THEORY AND PRACTICE

OF

THE ELECTRIC TELEGRAPH

A MANUAL

FOR OPERATORS AND STUDENTS,

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PREFACE.

THE number of very admirable works published of late, on the subjects treated in this manual, might seem to render its appearance quite unnecessay. The particular form, however, in which it is written, has been asked for by skillful teachers in the Telegraphic Colleges, and the work meets, therefore, only an imperative demand.

To students not already trained by a thorough general acquaintance with scientific subjects, the form of question and answer presents the readiest means of investigation, and of satisfaction, also, provided the questions are arranged in a natural and pro gressive order.

At the same time it precludes the construction of those condensed and comprehensive sentences that are often the delight of the advanced scholar.

At the risk of some repetitions, the answers in nearly all cases are so worded that the cursory reader may omit the questions entirely without losing the sense or the connection.

As to the subject matter a few departures from common method may be noted. First, language adapted only to theories not now generally received, is, as far as possible, discarded. Second. The idea of polar forces, and the principle of inductive action are made prominent early in the work so that each phenomenon may be explained as it occurs rather than in a general chapter at the end.

A little more attention is given to the secondary current than is usual in telegraphic manuals, the discoveries of Mr. Elisha Gray having brought the subject into new prominence.

Historical details have been for the most part omitted or briefly touched as the limit of such a work would permit.

In the chapters on practical telegraphy I have drawn freely from the works of Pond, Mattison, Pope and others who have written with much acceptance in this department.

C. H. C.

CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

GLOSSARY OF TERMS.

Ampere's Theory.—Magnets are constantly traversed by electric currents. See p. 35.

Anode.—Positive pole of a battery.

Armature.—Short bar across the ends of a horse-shoe magnet.

Astatic.—Without directive power.

Atoms.—The infinitely small particles of which all bodies are supposed to be made up, and which are capable of motion among themselves.

Aurora Borealis.—Electric streamers in the upper atmosphere.

Austral Magnetism.—That developed at the south magnetic pole of the earth.

Battery.—In frictional electricity, a set of Leyden jars connected together.

In voltaic Electricity.—One or more cells charged with the proper materials to produce a current.

Boreal Magnetism.—The magnetism of the northern magnetic pole of the earth.

Bunsen Battery.—Carbon batter, invented by Bunsen.

Capacity.—The quantity of electricity a jar, cable or other condenser can contain.

Cathode.—The negative (or zinc pole) of a battery.

Charge.— (verb.) To give a jar or cable its full quantity of electricity.

Charge.— (noun.) The electricity contained in any condenser.

Checking.—Attaching to a message a record of the number of words and of the tariff due or paid.

Circuit.—The whole path of a current from one pole of a battery around to the same point again.

Condenser.—Metallic plates arranged to act inductively on each other.

Dia-magnetic.—The non-conductor through which a magnet acts inductively.

Dielectric.—The air or other non-conductor through which electricity acts inductively.

Disguised Electricity.—That which does not affect an electroscope.

Electro-magnet.—Soft iron, surrounded by wires which have been previously varnished or else covered with silk or cotton.

Electro-motor.—An engine propelled by an electro-magnet.

Electric Storm.—Unusual development of atmospheric electricity.

Electro-type.—An engraving or any device for printing, which is reproduced in copper by the process of electro-plating.

Electro-plating.—Depositing on any surface, a plate of copper or other metal, by electricity.

Extra Current.—Current *induced* on the parallel coils of a single wire by the primary current on the same wire.

Farad.—The unit of force in electricity.

Free Electricity.—Either electricity separated from its opposite.

Galvanic.— Resulting from Galvani's discoveries. (The same as voltaic in practice.)

Galvanometer.—An instrument for measuring the force and direction of a current.

Helix.— (plural helices.) Wire bent in a spiral form.

Induction.—The excitement of one kind of electricity or of magnetism by its opposite.

Inductorium.—A large induction coil.

Insulation.—The separation of a body from all others by glass, air, or other non-conductors of electricity.

Key.—Instrument for opening or closing circuit.

Local Battery.—The battery used at a way station for registering the message.

Local Circuit.—The path traversed by the current of the local battery. It is confined to the office where the battery is.

Magnetic field.—The region or space throughout which a given magnet acts.

Main Battery.—That used at terminal stations.

Main Line.—The through wire between terminal stations.

Meridian.—(magnetic.) The direction assumed by the magnetic needle.

Meridian.—(geographical.)—The true north and south line through any point.

Ohm.—Unit of resistance.

Opening the Circuit.—Breaking contact so as to arrest the current.

Polarize.—To separate the two polar forces of a body.

Polarity.—Opposite forces of equal magnitude developed at the opposite ends of a given line called the axis.

Poles.—Points of maximum force in the opposite ends of a magnet or a battery.

Positive Plate.—The copper, carbon or platinum plate, from which (in the air,) the + current always flows.

Potential.—(electric.) Comparative electric intensity of a given point.

Residual Charge.—Left after the discharge of the Leyden jar.

Register.—The *Morse* recording instrument.

Relay.—An instrument attached to the main line for opening and closing a local circuit.

Resistance.—The opposition of any conductor to the flow of the current.

Rheostat.—A collection of resistance coils.

Sounder.—Instrument for reading a message by ear.

Spacing.—Practice in the proper separation of dots and dashes.

Secondary Current.—Current induced in a separate parallel wire by the current of a primary wire.

Shunt.—A branch circuit. If a bow-string represents a line wire, a portion of the current might be *shunted* by a separate wire around by the bow.

Solenoid.—A helix delicately suspended to act as a magnetic needle.

Telegram.—Anything sent by telegraph.

Thermo-electricity.—Electricity excited by heat.

Vertical Line.—The direction assumed by a plumb-line.

Volt.—The unit of force. About the force of one Daniell's cell.

Voltaic.—Resulting from the discoveries of Volta, an Italian.

Volta-meter.—An instrument for measuring the electro-motive force of a battery.

Signals.—The following signals are in common use upon railroad telegraphs. A few of them are also quite extensively used on commercial lines:

1.—Wait a minute.
2.—Important. Train orders.
3.—Give me correct time.
4.—Where shall I go ahead.
5.—Anything for me?
77.—Keep circuit closed.
8.—I have business for you.
13.—I (or we) understand.
18.—What is the matter.
22.—Busy on another line.
33.—Answer prepaid.
44.—Answer immediately.
73.—Accept my compliments.
134.—Who is at the key.
9.—Train Dispatcher's signal, has preference over everything.
12.—Is it O. K.? or, How do you understand?
C. & E.—Conductor and Engineer.

Abbreviations.—The number of words, everywhere alike abbreviated, is quite small. The table contains the few which are more commonly employed; others may be readily understood from their connection in most cases.

ABBREVIATIONS.

Abv.—Above.	G. N.—Good Night. Gone.	S. F. B.—Stop for breakfast.
Ads.—Address.	G.—Ground.	S. F. D. " dinner.
Ahr.—Another.	Hw.—How.	S. F. T. " tea.
Amt.—Amount.	Immy.—Immediately.	S. F. N. " night.
Ans.—Answer.	Inst.—Instrument. Instant.	Stk. Stock.
Ar.—Arrived.		
Brk.—Break.	Kw.—Know.	Smtg.—Something.
Bsns.—Business.	Msk.—Mistake.	Stix.—Sticks.
Cc.—Commence.	Msg.—Message.	T.—The.
Cd.—Could.	Msngr.—Messenger.	Tt.—That.
Ci.—Circuit.	Nn.—None.	Td.—To-day.
Co.—Company.	No.—Number.	Tff.—Tariff.
Condr.—Conductor.	Nsy.—Necessary.	Tk.—Think.
Chgs.—Charges.	O. K.—Correct,	Tnk.—Thank.
Dep.—Departed.		
Dg.—Doing.	Ofs.—Office.	Tm —Them. To-morrow.
Dw.—Down.	Ohr.—Other.	Trn.—Train.
D. H.—Dead Head.	Opr. or Op.—Operator.	Thru.—Through.
Ehr.—Either.	O. S.—Oh say.	
Ex.—Express.	Pa.—Pay.	U.—You.
Fr.—From.	Pls.—Please.	Ur.—Your.
Frt.—Freight.	Psb.—Possible.	Un.—Under
Fwd.—Forward.	Qk.—Quick.	Und.—Understand.
Guar.—Guaranteed.	Rr.—Repeat. Railroad.	V.—Very.
G. A.—Go Ahead.	Rtn.—Return.	Wk.—Weak. Week.
Gg,—Going.	Sd.—Should.	Wn.—When.
Gi—Give.	Sl.—Shall.	Wt.—What.
G. M.—Good Morning.	Ss.—Says.	X.—Next.

Words having certain terminations are also abbreviated in the following manner: Termination *ing* omits *in; ed, e; ion* or *ian, io* or *ia; ive, ic; ial, ia; ble, e; ful, u;* and *ess, s.*

CORRECTIONS.

1. A late rule agreed upon by the telegraph companies varies from that given under question 2, in the directions for checking on page 65. The new rule excludes from the address everything except the mere name, all else is counted and charged in the tariff.

2. On page 12, at the end of the answer to question 3d, under ¶ 13, read, "Shellac is a *poorer* insulator than air."

3. On page 86, third line from the top omit *only*.

4. Page 136, 27th line, Read Fig. 62 for Fig 60. Same on p, 137, 8th line.

THE MORSE ALPHABET.

Prof. Smith's Six Principles,

First.——Dots close together.

I	S	H	P	6
. .	. . .	. . . .	. . . . .	. . . . . .

Second.——Dashes close together.

M	5	¶
— —	— — —	— — — —

Third.——Lone dots.

E
.

Fourth.——Lone dashes.

T	L or cipher.
—	——

Fifth.—— A dot followed by a dash.

A
. —

Sixth.—A dash followed by a dot.

N
— .

L or cypher	T	E	I	S	H	P	6	A
——	—	.	. .	. . .	. . . .	. . . . .	. . . . . .	. —
U	V	4	N	D	B	8	G	
. . —	. . . —	. . . . —	— .	— . .	— . . .	—	— — .	
7	F	Comma	X	W	1	Q		
— — . .	. — .	. — . —	. — . .	. — —	. — — .	. . — .		
2	Period	3	M	5	Interrogation			
. . — . .	. . — — . .	. . . — .	— —	— — —	— . . — .			
9	K	J	O	R	&	C	Z	
— . . —	— . —	— . — .	. .	. . .	. . . .	. . .	. . . .	
Y								
. . . .								

These characters, forty in number, are formed of three simple elementary marks: the dot, the short dash, and the long dash. These elements, uncombined, are respectively E, T, and L or cipher. The remaining thirty-seven are made up of the dot and the short dash, the long dash never being used in combination, nor repeated except to repeat the letter or figure which it represents.

NOTE 1. Instead of the sign for italics, operators usually emphasize by spacing more widely the letters of a word.

2. The sign for parenthesis precedes and follows the words referred to. It is seldom used.

3. The period answers in almost all cases for the semicolon.

4. For directions and exercises in the alphabet see page 62.

CHAPTER I.

MAGNETISM.

1. The Magnet.—1. What is a magnet?

A certain ore of iron (first brought into notice near *Magnesia* in Asia) which has the property of attracting and holding small pieces of iron is called the *natural magnet* or loadstone.

2. What is an artificial magnet?

A bar of steel prepared for the purpose which has the same power as a loadstone is an artificial magnet.

3. What are the poles of a magnet?

1.

If a magnet be rolled in iron filings they will adhere to it in thick masses at two opposite points called the poles.

4. What is the neutral point?

At a point about midway between the poles the filings do not adhere; this is called the neutral point.

5. What is the axis of a magnet?

A straight line joining the poles is called the axis.

2. The Needle.—1. What is the magnetic needle?

A thin bar-magnet, pointed at the ends and properly balanced on a pivot is called a magnetic needle.

2. What property is revealed by the needle?

A magnet thus suspended will take a fixed direction with respect to the earth, called the magnetic meridian. It is nearly north and south.

3. What is this property of the magnet called?

This property is called the polarity or the directive power of the magnet. The term polarity, however, is not restricted to this use alone.

4. What other use has it?

The possession of opposite forces in the different parts of a body of any kind is called polarity. Two opposite forces are termed polar forces without reference to the general direction of their action. Directive power is but one result of polarity in a magnet.

3. *Names of Poles.*—1. What are different poles of a magnet called?

The end which points northward is called the north pole, marked **N** or + and the other is called the south pole, **S** or —.

2. Are the two poles alike in their effects?

Either pole of a magnet will take up small pieces of iron, in this they are alike.

3. How do they differ?

If a second magnet, called an ánalyser, be presented to a needle properly balanced, a new power is soon discovered, the power of repulsion.

4. Describe the experiment in detail.

First present **N** of the analyser to **N** of the needle; they repel each other. Next present **S** of the analyzer to **N** of the needle; they attract. In like manner try **S** of the needle with each pole of the analyser.

4. *Law of Magnets.*—1. State the law of attraction and repulsion.

Poles of the same name repel. Those of opposite name attract each other.

2. What is the effect of placing the analyser over the center of the needle and at right angles to it?

The needle will place itself parallel to the analyser in every case and will stand with its **N** pole adjacent to **S** of the analyser.

5. *Division of the Magnet.*—1. What is the effect of dividing a magnet?

If a magnet is divided into any number of parts, each part will be a perfect magnet, having its two poles and a neutral point.

6. *Magnetics.*—1. What are magnetic bodies?

By magnetic bodies iron and steel only are meant, as these alone are capable of possessing an amount of magnetism easily appreciable.

2. What other bodies can have feeble magnetism?

Nickel, cobalt, copper and several other bodies are slightly susceptible of magnetic influence.

7. *Coercive Force*.—1. Are iron and steel alike in their susceptibility?

Soft iron becomes a magnet readily and loses its power instantly. Hard iron is slower both in gaining and losing the force. Steel resists with energy and therefore retains its magnetism permanently.

2. What is this resisting power of steel called?

The resistance offered by steel to becoming a magnet or to losing its magnetism is called its *coercive* force.

3. How can it be overcome?

The coercive force is diminished by heat or by gentle blows with a hammer or by anything which causes motion of its atoms, such as filing, grinding and polishing. A white heat entirely destroys it.

4. Is coercive force dependent on hardness?

It is. No iron can be found so soft or pure as to have no coercive force at all, and no steel is so hard that it cannot be magnetised, or that it will forever retain the force when once acquired.

8. *Induction*.—1. What is meant by induction in physics?

Induction is the awakening or excitation of a polar force by its opposite.

2. Give an example of magnetic induction.

If one end of a steel bar be rubbed by the **N** pole of a magnet, **S** magnetism is excited in that end by induction.

3. Does the rubbing magnet lose any of its magnetism by transfer?

There is no transfer. Magnetism is never imparted but always induced.

4. How are artificial magnets made?

If a bar is to be magnetized, lay it on a table and bring the poles of a **U** magnet down upon its center with the **N** of the **U** magnet towards that which is to be the **S** end of the bar, slide the **U** back and forth on the bar, never beyond the ends, then turn the bar over with its ends the same way and repeat the process on the other side. Take the **U** off at the center of the bar when the process is complete.

5. Can induction take place without contact?

Contact is not necessary to induction, though the nearer the bodies are, the stronger and more rapid the inductive effort. Friction too assists in the process.

6. How can steel of great coercive force be magnetized?

If the steel bar be very hard, place it endwise between opposite poles of two powerful magnets, heat it by a spirit lamp to a dim redness, then suddenly cool it while in that position.

7. Will a bar of soft iron influence the magnetic needle?

Soft iron will instantly *attract* either pole of the needle but never repel.

8. Why does it not repel one of the poles?

Soft iron held near either pole of the needle becomes itself a magnet by induction. The part of the iron nearest that pole is necessarily of the opposite name and attracts it.

9. What proof is there that the soft iron is a magnet while near the needle?

If a second and weaker needle be brought near the other end of the iron, one of its poles will be attracted and the other repelled. Also the iron will take up filings at both ends.

10. How does an unmagnetized steel bar affect the needle?

Steel at first has but little influence on the needle, but held for some minutes near one pole it will feebly attract it, but that part of the steel will now repel the other pole.

11. Why so?

This is because the magnetism induced in the steel by the needle is permanent, as was not the case with soft iron.

12. Do non-magnetic bodies prevent or hinder induction?

The interposition of glass, air or other non-magnetic bodies between a magnet and a piece of iron does not at all diminish the inductive effect.

9. Dia-Magnetics.—1. What are these bodies called?

These bodies are called dia-magnetics because the magnetism passes readily through them. More properly they convey the magnetic influence by a peculiar change in their own particles.

10. Successive Induction.—1. What is the effect of bringing the opposite poles of two magnets together?

The **N** pole of one magnet will act inductively on the **S** pole of another in contact with it; the action will be reciprocal and the power of both will be increased.

2. Is there any limit to this?

These reactions soon reach their limit as each successive induction is more feeble than the preceeding one.

3. Why is a magnet usually bent in the U form?

The form U favors inductive action between the opposite poles of the bar, so that the two will take up a weight considerably more than twice as heavy as one alone would raise.

11. Armatures.—1. How is the magnetism of the U preserved?

A short bar of soft iron, called a keeper, is placed across the ends of the U. This becomes a magnet and by its reaction keeps up the power of the U magnet.

2. How can a straight bar be armatured?

By surrounding it in any way with masses of soft iron any magnet will be kept.

3. Does hanging a weight to a magnet strengthen it?

A weight is of no use unless it is of iron and so near as to act inductively. The fact of suspension is of no importance.

4. How is the compass needle kept?

The compass needle should always be free to place itself in the magnectic meridian when not in use. The earth acts upon it by induction precisely as if it were itself a huge magnet.

12. Astatic Needle.—1. What is an astatic needle?

A needle, which, though a magnet, has no directive power is called astatic.

2. How can the directive power of a needle be neutralized?

A bar magnet held over a needle will overcome the earth's magnetism thus rendering it astatic. A long needle can have its extremities both **N** while its centre is **S** or vice versa. Such a needle will have no directive power.

3. Has such a needle polarity?

It has polarity in the second or general sense, but will not point **N** and **S**.

4. What is an astatic system?

Two parallel needles fastened with brass or wood a little distance apart and so suspended that their opposite poles are adjacent to each other will constitute an astatic system.

5. Of what use are they?

Astatic needles or systems are useful in detecting the presence of magnetic forces too feeble to over-come the earth's magnetism.

13. Theories.—1. Why is the intensity of the magnetic force greater at the poles than in the center of a magnet?

FIG. 2.

All the atoms of a magnet are regarded as polarized, that is, each atom is a separate magnet, Fig. 2, and all have their **N** poles in the same direction. At the center both forces exist, but at one end northern magnetism is free, and at the other southern. Hence at each pole a peculiar force is apparent.

2. Do we have at the poles merely the force belonging to one layer of atoms?

No. From the arrangement of the atomic magnets the force is necessarily cumulative towards opposite ends.

3. Illustrate this?

Suppose a bar of iron, suspended by its middle point, to be expanded in legth by heat; the expansion is most noticeable at the extremities and not at all in the center. At the ends is the accumulated motion of all the atoms.

4. What experiment illustrates the polarization of the atoms?

Fill a small thin glass tube with honey in which a great number of short bits of iron wire have been stirred; seal it and place the tube lengthwise between the opposite poles of two powerful magnets. The bits of wire become magnets, and turn their **N** poles all the same way; but the tube will as a whole be neutral in the center, and strongly polarized at the extremities.

5. If steel wire were used in the experiment would the the tube remain a permanent magnet?

It would.

6. On this theory what it the condition of an unmagnetized bar?

In an ordinary piece of iron or steel the two opposite forces **N** and **S** magnetism are *united* and *neutralized.*

7. What is it to magnetize the bar?

To magnetize a bar is simply to separate the two magnetic forces in each atom, as was done in each bit of wire, and thus to polarize the whole mass.

8. How then do you account for the difference between soft iron and steel?

Iron is in some sense a *conductor* of magnetism allowing the two forces easily to unite again and neutralize each other the moment the inducing agent is withdrawn, while steel obstructs the movement.

9. Does magnetizing a body affect its size or form?

An iron rod is slightly lengthened on becoming a magnet, and it shortens instantly on losing the force.

10. Can a powerful magnet be made by means of a weak one?

It cannot. In magnetizing a bar the most powerful magnet possible should be selected as induction, even then, is never perfect.

CHAPTER II.

STATIC ELECTRICITY.

1. How does electricity resemble magnetism?

Electricity like magnetism includes two polar forces which in their unexcited state entirely neutralize each other, giving no sign of their presence.

2. How do they act when separated?

When separated the two opposite forces powerfully attract each other and if not prevented reunite with a violent shock attended with light, heat and sound.

3. What names are given to these opposite forces?

One force is called positive electricity marked + and the other negative or —. Sometimes the first is called vitreous and the second resinous electricity.

4. What is the origin of the names positive and negative?

Franklin supposed there was but one kind of electricity. Its presence in unusual quantity he called the positive state and its absence the negative. This theory is now obsolete but the terms are still in use.

5. How did the other names come in vogue?

Vitreous or glazed substances were found to yield positive electricity and resinous bodies negative.

2. *E lcrics.*—1. What are electric bodies?

Electricity is not confined like magnetism to a few substances, but all bodies are susceptible of it. All bodies are therefore properly electrics.

The term electrics was at first applied to glass, sulphur, shell-lac, amber and a few other substances which alone were supposed capable of the electric excitement.

2. Has electricity has any other point of resemblance to magnetism?

Electricity like magnetism exhibits repulsion as well as attraction and each force seems self-repellant.

3. Law.—1. What is the first law?

Like electricities repel, and opposite electricities attract each other.

4. Transference.—1. In what respect does electricity especially differ from magnetism?

Unlike magnetism, either kind of electricity may be transferred from one body to another, the first apparently losing what the second gains. Also a body may have one force to the exclusion of the others.

5. Separation of the two Electricities.—1. What if a body polarized by electricity should be divided?

If the polarized body is cut at the neutral point, one half will contain + electricity and the other —. [See section 5.]

3. Can one force exist without the other?

Yet one force is always attended by the other in its immediate vicinity, upon which it reacts.

4. Can either force be stored up for use?

Either electricity may be forcibly separated a small distance from the other and thus be stored up for experiment.

5. What is the second law of attraction and repulsion.

Since electricity attaches itself to certain bodies with some force, in its movement it carries the bodies with it. Hence the second law,

Bodies charged with like electricities repel each other; those charged with opposite kinds attract.

6. Why will not one law cover all cases?

The first law explains only inductive action; the second the movement of electrified masses.

6. Development of Electricity by Friction.—1. How is electricity developed?

Rub dry warm glass with silk. The electricities will be separated by the friction, the positive remaining on the glass (which is now said to be *excited*), and the negative going to the rubber.

2. How can negative electricity be captured?

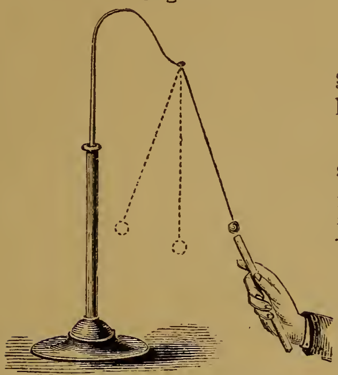
Rub dry sealing wax or ebonite with flannel. The negative remains on the wax and the positive goes to the rubber.

7. Electroscopes.—1 What is an electroscope?

Any instrument used to detect the presence of electricity is an electroscope.

2. Describe the common forms.

Fig. 3.



Pith Ball Electroscope.

A pith ball suspended from a glass support is called a pendulum electroscope.

The gold leaf electroscope consists of two narrow strips of gold foil suspended together in a glass jar from a metallic rod which passes up through the cap and terminates in a metallic plate or a ball.

8. ***Experiments.***—1 What experiment can be tried with the pith ball electroscope?

Hold the excited glass near the pith; three distinct results follow:

First, the glass *polarises* the pith ball;

Secondly, it *attracts* it;

And, thirdly, it *repels* it.

2. Explain the first result.

The glass being positively charged, separates by induction the compound electricity residing in the pith, drawing the negative to the side next the glass and forcing the positive to the opposite side, according to the first law of attraction and repulsion.

3. Explain the second result.

The glass and pith, having now opposite forces face to face, obey the second law and attract each other.

4. Why do they finally repel each other?

As soon as the pith strikes the glass its negative electricity is neutralized by an equal portion of positive from the glass, and having now only positive it is repelled according to the second law.

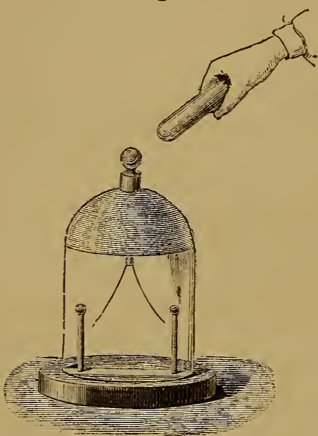
5. How will the excited wax effect it?

While the glass repels, the wax attracts it. It will vibrate between the two so long as sufficient force remains to move it.

6. How is the gold leaf electroscope used?

The gold leaf electroscope exhibits repulsion first, or repulsion alone.

Fig. 4.



Gold Leaf Electroscope.

The excited glass is held several inches from the knob and the gold leaves at once diverge When the glass is removed they collapse.

7. Why do they diverge?

The knob and leaves are polarised by induction, their negative force being drawn to the knob and their positive driven to the leaves which now having positive electricity only, repel each other and diverge.

8. What if the glass touch the knob?

It the glass touch the knob a spark will pass. The knob and all the metal will now be charged with positive electricity by transfer. The leaves will permanently diverge till the charge is taken off or neutralized.

9. Suppose excited sealing-wax be used instead of glass, in these experiments?

If wax or ebonite be used the phenomena will be the same, though the kind of electricity is precisely the opposite in each case.

9. Spheres of Influence and of Communication.—1. What is meant by the sphere of influence of an electrified body?

When any thing is near enough to an electrified body to feel its inductive power it is said to be within the sphere of influence.

If it is near enough to receive a spark it is said to be within *striking distance* or within the sphere of communication.

2. How is each found?

The gold leaf electroscope may be used to ascertain approxmately the sphere of influence. But it doubtless extends far beyond the point at which any electroscope will move, the polarization being more feeble the farther we retreat from the excited or charged body.

10. Conductors.—1. What are electrical conductors?

Bodies over which the electrical force passes easily are called conductors. Those over which it passes with difficulty, or to which it seems to adhere, are called non-conductors or insulators.

2. Illustrate this?

Suppose a glass cylinder rounded at the ends, to become polarized, *i. e.* to have at one extremity + electricity, and at the other —. Notwithstanding their powerful attraction, yet, since the glass is a non-conductor, the two electricities will long remain separate, but if the cylinder were of brass or any metal they would instantly unite.

3. What analogy between electricity and magnetism does this reveal?

The glass seems to have coercive force, called in electricity *resistance* and so retains its polarity like a steel magnet, the brass (like a soft iron magnet) offers little resistance to the movement of the forces and so instantly loses its polarity when left to itself.

11. Non-Conductors.—1. What is insulation?

Insulation is the surrounding of a body with non-conductors so that it can neither lose nor receive electricity.

2. Are there any perfect insulators?

No perfect insulators have been discovered, and no perfect conductors, and there are all possible degrees between known extremes of resistance in different substances.

3. Give a table of conductors and insulators in the order of their conducting powers?

CONDUCTORS.	INSULATORS.
Metals.	Ice.
Charcoal.	Glass.
Plumbago.	Dry Fur.
Melted salt.	Silk.
Water.	Diamond.
Live or moist flesh.	India Rubber.
Vegetable fibre.	Ebonite.
Oil.	Resins.
Spermaceti.	Amber.
	Shell-lac.
	Dry air and Gases.

The nearer the beginning of the list any substance is, the better its conducting power. The nearer the end, the better

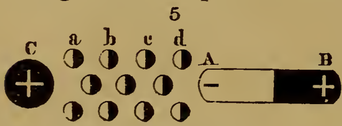
its insulating power. Thus ebonite (hard rubber) is a better insulator than glass, while shell lac is better than ebonite.

4. How is the insulating power of glass improved?

Glass varnished with shell-lac is a better insulator, as the lac keeps away moisture which is liable to settle on the glass.

12. ***Theory of Induction.***—1. How can the electrified body act at a great distance from itself!

Faraday's theory is, that the air, or whatever non-conductor intervenes between the electrified body and the object influenced is itself polarized in every atom by induction. In the figure let **C** represent the electrified body and **A B** the object to be influenced; **a b c d** etc., will represent atoms of air, the white half of each indicating the negative side, and the dark the positive side. Through the action of these contiguous atoms the influence is conveyed to **A — B** which in this manner becomes polarized.



13. ***Dielectrics.***—1. What name did he apply to these intervening bodies capable of polarization?

The intervening bodies he named *Dielectrics* as those conveying magnetic force were called Dia-magnetics.

2. What bodies convey the force the best?

Generally the best *non*-conductors are the best *in*ductors or dielectrics, though there are some exceptions.

3. What experiment shows this exception?

Let a small disc of brass, instead of the knob, be screwed to the top of the gold leaf electroscope, and let another disc of equal size be suspended just above and parallel to it. Now charge the upper disc very slightly till the leaves diverge about an inch. Next push a cake of shell-lac, with an insulating handle, between the disks. Shell-lac is a ~~better~~ poor insulator than air and the leaves instantly diverge more.

14. ***Specific Induction.***—1. What is this power of conveying inductive effects called?

This power is called specific inductive capacity.

2. Give Harris' table of insulators with the inductive capacity of coch?

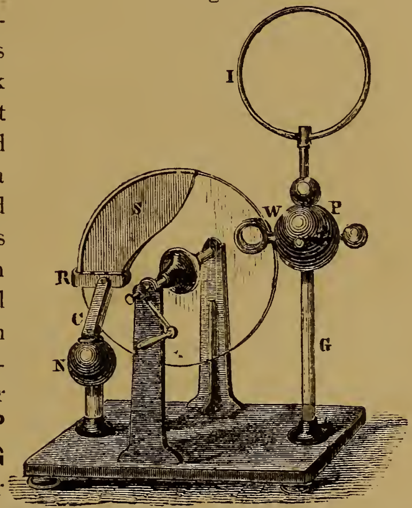
Air - - - -	1.00	Beeswax - - -	1.86
Resin - - - -	1.77	Glass - - - -	1.90
Pitch - - -	1.80	Sulphur - - -	1.93
	Shell lac - - -	1.95	

15. Electric Machines.—1. What are electric Machines?

An electric machine is any contrivance by which static electricity is rapidly produced.

2. Describe the plate machine?

Fig. 6



The plate machine consists of a circular glass plate turned by a crank between rubbers of soft leather **R** which are held firmly against it by a spring **C**. A ball **N** called the negative conductor has metallic connection with the rubber, The plate and rubbers are mounted on insulating supports. Opposite the rubbers is either a brass ball or a cylinder **P** mounted on a glass pillar **G** called the prime conductor which is furnished with a row of brass points at **W** and is sometimes surmounted by a wooden ring **I**, enclosing an iron ring. A silk covering **S** assists in confining the electricity to the plate on its passage to the prime conductor.

3. Taken together what are **P** and **N** called?

The prime conductor and the negative conductor or rubber constitute the two poles of the electric machine.

4. How is the machine prepared for vigorous action?

The whole machine must be quite dry, warm and free of dust. The insulators especially must be carefully kept dry. The plate should be clean, and the rubbers smeared next the plate with amalgam from the back of a piece of looking-glass. A chain should be appended to the rubber and if possible have complete metallic commuuication with the earth.

16. Experiments.—1. What are some of the effects?

When the handle is turned, a sharp crackling noise is heard, sparks of fire leap along the plate, brushes of flame appear at all points and edges and the smell of ozone is plainly discernible.

2. What is its effect on the person?

If a knuckle be held to the prime conductor a bright spark passes accompanied by sound and a prickling sensation.

3. What is the effect on adjacent bodies?

The ball of the pendulum electroscope is attracted toward the prime conductor, the leaves of the gold-leaf electroscope diverge even if several feet distant. If a brass ball be presented a bright, broad spark passes with a loud report.

17. Intensity and Quantity.—1. Upon what does the size, length and brilliancy of a spark depend?

They depend upon the *intensity* and the *quantity* of electricity in the prime conductor and on the size and conducting power of the ball.

2. What is meant by intensity?

Intensity, sometimes called *density*, relates to the amount of force collected *on a given surface*: for example, two turns of the machine will convey twice the intensity to the same prime conductor that one will. This ratio will be maintained till the prime conductor has all it can retain.

3. What governs quantity?

Quantity with a given intensity depends on the size of the prime conductor. A prime conductor of one hundred feet surface will, with the same intensity, contain twice as much as one having but fifty feet.

4. How is this illustrated by heat?

A red-hot knitting-needle has the same *intensity* of heat as a red-hot poker, but a much smaller quantity. Again, a large stove, at low temperature, will warm a room as much as a small stove red-hot. Here the *quantity* in the source of heat may be the same but the *intensity* different.

5. Give corresponding examples in electricity.

A cloud, miles in extent, may be feebly charged while the quantity in the aggregate is enormous. On the other hand, the largest machines give but small quantity as compared with a cloud, but exhibit the highest intensity.

18. Tension.—1. What is electric tension?

Tension is the tendency to leap from a charged surface. It depends upon the intensity but must not be confounded with it. The tension increases much faster than the intensity. Laplace teaches that tension increases as the square of the intensity.

19. The Machine Polarized.—1. In what state is the machine when in action?

In action and just afterwards, the machine is polarized the positive electricity remaining on the prime conductor and the negative on the rubber and its connections.

20. Discharge.—1. What is it to discharge the machine?

To discharge the machine is to restore the equilibrium by allowing the + and — electricities of the prime conductor and rubber to reunite.

2. What are the methods of discharge?

There are three modes of discharging the machine called the *conductive* the *convective* and the *disruptive* discharges.

3. Describe the first.

Suppose both poles of the machine to be insulated:

1. Before the handle is turned, connect the rubber with the prime conductor by a wire or chain. Then on operating the machine the separated electricities silently reunite over the path thus provided, forming a feeble electric current. This is the *conductive* discharge.

4. Give the second mode?

If the machine after turning is allowed to stand awhile, the particles of air near each conductor become charged with the opposite forces, and by their motions finally produce equilibrium. This is the *convective* discharge.

5. How may this movement of the air be perceived?

The movement of the charged particles of air as they are repelled from the machine may be felt on the face or hand held near either conductor. Sharp points directed toward the machine or attached to it greatly favor this discharge.

6. The third mode.

Let one end of a chain or wire be fastened to the rubber and the other to a brass ball which has a glass handle; bring the ball within striking distance of the prime conductor. The forces now unite with an explosion. This is called the *disruptive* discharge.

21. Connection with the Ground.—1. What is the effect of connecting the rubber with the ground?

By far the most important practical effect is to form part

of a circuit, from the rubber around through the earth , toward the prime conductor. So that the operator standing on the floor, which also has connection more or less perfect with the earth, can complete the circuit at will, and get a free discharge from the prime conductor.

2. How does it place every uninsulated body?

Every uninsulated body is thus placed in direct connection with the rubber or negative pole of the machine.

3. Is the chain *usually* attached to the rubber?

It is always assumed that the chain is to connect the rubber with the earth, unless the contrary is indicated.

4. Can the same effect be obtained in any other way?

This effect can be obtained by covering the floor, where the experiments are tried with metal, which communicates with the rubber.

5. Does the rubber retain its negtive charge in that case?

If the rubber is nearer the prime conductor than any other part of the conducting medium, it shows decided polarity. Otherwise the negative electricity is drawn away from the rubber to that point of the uncompleted circuit which is nearest the prime conductor.

22 Limited Charge.—1. Why is the charge limited when both rubber and prime conductor are insulated?

The charge at either pole is not limited in supply, it is simply held fast by the mutual attraction which the two forces have for each other. Let a path be made between them as described for the disruptive discharge and the supply seems unlimited except by the size and power of the machine.

23. Free Electricity.—1. Is not the electricity of the prime conductor more *free* when the rubber is uninsulated?

The positive electricity is no more free to go back to the rubber *i, e.* to meet the negative in one case than in the other. It is more free to take a circuitous route through other bodies, and through the earth, and that is all that can be meant by the term free.

24. Raito of In'ensity and Qaantity.—1, Can a *very large* prime conductor be charged as well when both poles of the machine are insulated?

A large prime conductor can be as well charged as a small one, provided the insulation is perfect, and the *negative conductor is of equal size with the positive.*

2. What if it is not of equal size?

The *quantity* of the negative and positive forces being equal, if the negative conductor is small and insulated, its charge soon reaches so high a tension that disruptive discharge over the glass follows. The intensity of the two conductors is in the inverse ratio of their surfaces.

25 Enlarging one of the Conductors.—1 What then is the second effect of connecting the rubber with the earth?

Connecting the rubber with the earth is the same as making the negative conductor as large as the earth. Its intensity will therefore be as much less than that of the prime conductor as the surface of the prime conductor is less than that of the earth, or practically zero.

2. Has the rubber then no polarity when connected with the earth?

If the rubber is nearer the prime conductor than any other conducting medium, which communicates with the earth, it is still somewhat polarized by induction from the prime conductor.

26. Diversion Of Inductive Influence.—1. How is it that we can obtain small sparks from either conductor when both are insulated?

Though the mutual attraction is strong between the two conductors, yet a third body brought quite near either will share the inductive influence and become polarized and may exchange electricities with it to a small extent.

27. Permanent Charge.—1 How can a permanent charge be imparted to a body?

A permanent, positive charge may then be obtained, if the rubber is uninsulated, by first insulating the body and then connecting it with the prime conductor. This in effect makes it a part of the prime conductor. It may afterwards be separated from it but will retain the charge.

2. How can the negative charge be secured?

Connect the prime conductor with the earth and attach the insulated body to the negative conductor. It will become negatively charged when the plate revolves.

28. Effect of Insulation.—1. What force binds a charge to the surface of anything?

The charge remains on any thing for want of a conductor to allow it to escape. The better the non-conductor that surrounds it the more firmly is it held.

2. What was the old theory?

It has been taught that atmospheric *pressure* holds the charge, but Faraday's theory of dielectrics (sec. 25, Chap. 2,) makes this extremely improbable if not impossible.

3. Why then is it that a charge of higher intensity may be given in condensed than in rarified air?

Rarefied air becomes more easily polarized and is a better conductor than dense air.

29. ***Distribution of Charge.***—1. Is the intensity of a charge everywhere alike?

If the prime conductor is a sphere the intensity is uniform; if a cylinder, with rounded ends, the intensity is greatest at the extremities and nearly neutral in the middle. The force will accumulate on every projection.

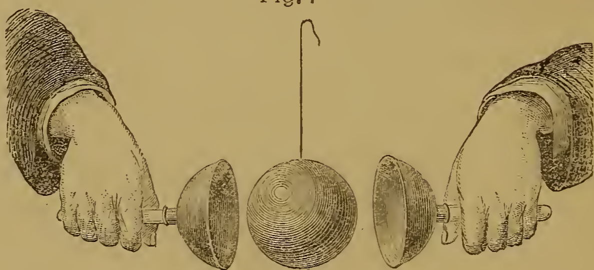
2. Does the charge reside on the outside or does it pervade all the atoms of a body?

It manifests itself on the surface only. A hollow cylinder will receive as high a charge as a solid one.

3. What experiment proves this?

A sphere covered with hemispherical cups with glass handles loses all its electricity if the cups are removed.

Fig. 7



4. Is there any exceptions to this?

Where the intensity is great and long continued especially on the surface of poor conductors the charge will penetrate and the cups must be used more than once to remove it.

30. ***Insulating Stool.***—1 What is the apparatus for charging the human body?

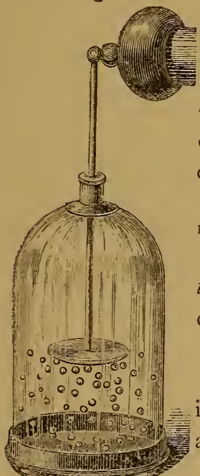
An insulating stool having glass or ebonite legs is provided on which a person may stand and take hold of a chain attached to one of the conductors.

31. ***Experiments.***—1 What amusing experiments are made?

A person thus charged may with his finger set fire to ether or to benzine or to powdered resin; can light the gas, fire a hydrogen pistol or communicate a shock to others. His hair if dry and free, will stand erect.

2. Experiments with other apparatus?

Fig. 8



Mimic Hail Storm.

Amongst other things bells are rung; images are caused to dance or swing; a mimic hail storm is produced by suspending a plate of brass within a glass jar, over small pieces of paper or pith, which have been scattered on the metallic floor of the jar.

32. *Variety of Machines.*—1 What other electric machines are in use beside the plate machine?

The *Cylinder* machine, the *Hydro electric* machine and the *Holtz* machine are in common use.

2. Describe the cylinder machine?

The cylinder machine has a glass cylinder instead of a glass plate, which is turned by a crank against a silk rubber.

3. What is the hydro-electric machine?

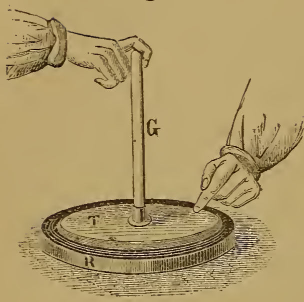
A small steam boiler is mounted on glass legs and the steam issuing from narrow wooden pipes, generates large quantities of electricity by the friction thus produced.

4. What is the Holtz machine?

The Holtz machine, so called from the name of its inventor, consists mainly of two thin circular plates of glass, one of which revolves with great rapidity very close to the other which is stationary. The stationary plate is charged negatively at one or two points by striking it with cats fur. The revolving plate is charged by induction from the stationary one and its electricity may be taken off by means of a row of points, as in the other machines. It is extremely effective, furnishing electricity in great quantities, and high tension without friction.

33. *Electrophorous.* What is the Electrophorous?

Fig. 9



Electrophorous.

The electrophorous consists of a cake of resin, shell-lac or ebonite, cast in a shallow plate of tin or iron **R**, and a movable tin cover **T** which has a glass handle **G**.

2. How is it charged?

If the cover is removed and the resin struck a few times with cat's fur or flannel, the cake will be charged with negative electricity. The cover on being replaced becomes charged, by induction, with positive electricity on its lower side and with negative on its upper side. If we touch the finger to the upper side to let the negative escape, we may immediately after lift up the cover by its insulating handle, and it will be charged with positive electricity and will yield a spark.

3. Does this discharge the cake?

This does not discharge the cake but the process may be repeated an indefinite number of times.

4. Why does not the second contact of the cover discharge the resin?

Perfect contact no doubt would; but the contact is slight and at few points. The cake is a non-conductor and the tension is extremely feeble.

34. ***Electric Condensation.***—1 How can the charge of the prime conductor be intensified?

Let two insulated plates of metal be placed a few inches apart facing each other and let wires connect one with the prime conductor the other with the rubber. The intensity of the two plates will be much higher than could be given to either of the conductors.

2. Why is this?

It practically brings the two poles of the machine nearer together causing two results.

1st. Successive inductions arise analogous to the reactions of two magnets, which greatly increase the intensity.

2d. The polar forces by their mutual attraction capture or *disguise* or practically neutralize each other, so that neither

will leave its plate or manifest its pressure by the electroscope.

3. What is the common form of this experiment?

The common method is to insulate the first plate and connect the second with the ground. The first will then receive repeated charges from the prime conductor.

4. How can this intensity be further greatly increased?

Let now a pane of glass take the place of the air as an insulator between the plates, and we can bring them much nearer together without a discharge. The glass in no wise hinders inductive action while effectually holding separate the two poles.

5. In what case would induction be the greatest possible?

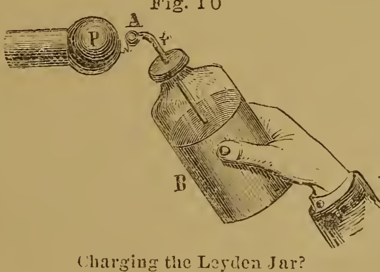
If the glass were infinitely thin and yet strong the induction would be perfect. As it is, extreme intensity can be given till the disruptive discharge takes place shattering the glass.

35. Leyden Jar.—1. What is the best form of this apparatus?

The Leyden jar is the most convenient apparatus made on this principle. It is a glass jar, coated inside and out, except a few inches at the top, with tin-foil. It is stopped with a varnished wood cap, through which passes a stout wire to the inner coating. At the top of the wire is a brass knob.

2. How is the jar charged?

Fig. 10



Charging the Leyden Jar?

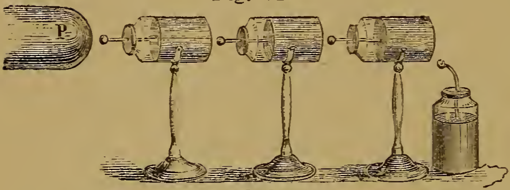
It is charged by holding it in the hand with the knob to the prime conductor. The hand furnishes a path for positive electricity driven off from the outer coating, and for the return of negative from the rubber, or the earth.

3. How do we know that any positive electricity is driven off?

The presence of positive electricity on the inner coating of the jar makes it necessary according to the first law of attraction and repulsion, but a confirmation of the fact is afforded by the cascade *series*.

36. *Cascade Series.*—1. Describe the experiment in detail?

Fig. 11.



Cascade Series.

A series of Leyden jars is so arranged on insulating stands that the knob of each successive one shall communicate with the outer coating of the one before it. The last of the series is uninsulated. Charge the first and remove the jars by means of the insulating stands and all will be found charged alike.

2. How is this explained?

Each knob, after the first jar, is positively charged from the outer coating of its predecessor, giving up its negative in exchange, and leaving each jar polarized. The last of the series receives its negative from the rubber through the ground.

37. *Quantity in a Charged Jar.*—1. Does a charged jar contain more electricity than one not charged?

A charged jar has no more electricity than when neutral. It has merely substituted negative for what positive it had in its outer coating and positive for the negative of its inner coating.

2. What then is the true condition of a charged jar?

A charged jar is simply polarized, the two coatings being in opposite and equal states of intensity.

3. What modification of this statement should be made?

In the common way of charging the jar, the connection ot the outer coating with the rubber is imperfect, and the thickness of the glass prevents perfect induction, so that when the charge is finished there is usually in the interior, a slight excess of the positive electricity. If the connections are equally good there is no difference whatever.

4. Can this excess be thrown into the outer coating?

If the jar is held by the knob and the outer coating be presented to the prime conductor the jar will be charged negatively, and a positive excess will be found in the outer coating. All this is reversed if the prime conductor is uninsulated and the charge is taken from the negative pole.

38. Discharge by Instalments.—1. If the charged jar be insulated, will the knob yield a spark?

When there is an excess it will yield it, of course, and if it is perfectly polarized and a good conductor is brought *nearer the knob* than the *coatings are to each other*, a relation is established exactly like that between the coatings, only less extensive, and a slight discharge takes place leaving a small excess in the outer coating. The outer coating will then yield a spark, reducing its intensity a little below that of the interior and so on.

2. Why cannot the *first* spark be taken from the outer coating?

If the jar stands on an insulator while being charged having metallic connections with the poles of the machine for both coatings, the first spark *may* be taken from either coating. But *handling* the jar, as in the usual mode of charging, always leaves the excess in the inner coating. The thinner the glass the less is this excess.

39. Triple Coating Jar.—1. How is the relation (alluded to in Sec. 38) of a third body to the inner coating shown?

Let a jar of ebonite in the form of a large tumbler, be turned to the uniform thickness of the eighth of an inch and provided with accurately fitting, movable coatings. Let now a second jar, exactly fitting this on the outside, be made half as thick and coated only on its outer surface. Charge the first jar in the usual way and place it inside the second, on an insulator; connect the innermost and outermost coating. The + electricity will leave the innermost coating and come outside so as to be nearer the middle or — coating. We may now remove the inner jar with its interior coating, the outer jar will remain charged.

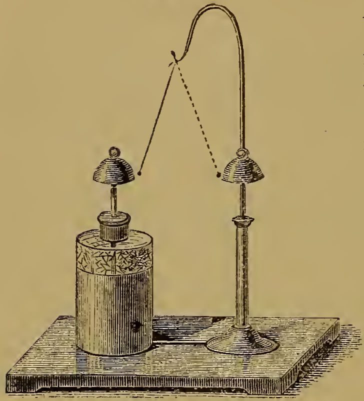
2. What does this experiment prove?

This proves that the electricity of either coating is *free* to leave it provided it is thus brought nearer its opposite force. The knob is a small portion of the inner coating. The knuckle or other conductor brought very near it is like part of a third coating.

40. Automatic Discharge.—1. What apparatus exhibits the discharge by instalments?

Between two bells which are connected with the outer

Fig. 12.



Automatic Discharge.

and inner coating a small brass ball is suspended by a silken fibre. The ball will vibrate till the jar is discharged.

2. In what other way is this performed?

A modification of this experiment is often made by charging one jar from the prime conductor and another from the negative conductor, a ball will vibrate between the knobs till they are discharged.

41. ***Charging an Insulated Jar.***—1. Can an insulated jar be charged?

An insulated jar can receive but a feeble charge, there being no path for the escape of positive electricity from the outer coating, or the return of negative from the rubber. The inner coating of such a jar would be merely an extension of the prime conductor.

42. ***Discharge of The Jar.***—1. How is the jar discharged?

A wire fork terminating in brass knobs and having a glass or ebonite handle is used to make metallic connections between the coatings without exposing the operator to the effects of the shock.

2. How may the shock be taken?

If one wishes a shock he has but to place one hand against the outer coating and touch the knob with the other.

43. ***Electric Battery.***—1. What is an electric battery?

A battery consists of any number of Leyden jars, standing on tin-foil and having their knobs connected by a wire. For convenience, they are usually placed in a box, from one side of which a knob extends, which has connection with the external coatings.

44. ***Use of the Coatings.***—1. Of what use are the coatings of the jar?

The coatings are the first to be polarized when the jar is charged, and they spread the charge instantly over the surface of the glass. Without such a conducting medium the

glass could only be charged slowly and irregularly in different parts.

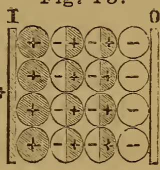
2. Does the charge reside in the coating?

The coatings merely conduct the electricity. If a jar has movable coatings they may be severally removed but the electricity remains on the glass.

45. *Polarization of the Glass.*—1. In what condition is the glass then?

Glass being a dielectric its atoms are polarized as represented in the figure. The distance **I O** represents the thickness of the glass, **I** the inner coating and **O** the outer. The particles next the inner coating are *positively charged* and those next to **O** *negatively*, while the intervening particles are simply *polarized.*

Fig. 13.



46. *Residual Charge.*—1. What is the residual charge?

A second discharge may be obtained if the jar has stood charged any considerable time, because the charge has penetrated the glass to other layers beyond those nearest the coatings and is slow in coming to the metallic surface.

47. *Disguised Electricity.*—1. What name is given to the polarized forces of the jar which do not affect the electroscope?

All the electricity of the jar, except the slight excess which has been referred to, is called *disguised electricity;* because, like the compound force, it does not affect the electroscope. Actually combined forces are only more effectually disguised.

2. Is disguised electricity found only in jars or other condensing apparatus?

It is found to a certain extent in the two conductors of the electric machine when both are insulated, and in general whenever two bodies charged with opposite forces are near enough together to act inductively on each other.

47. *Spontaneous Discharge.*—1. Does a jar ever discharge itself spontaneously?

The *disruptive* discharge frequently occurs over the glass, from the upper edge of one coating to the other. An intense charge always tends to creep up the glass. If the jar is thin the disruptive discharge often takes place through the glass, destroying the jar. The *silent* conductive discharge is accomplished when the glass is moist. The air will in time silently accomplish the *convective* discharge, though a hermetically sealed jar will sometimes retain a charge for months.

49. Electric Light.—1 What causes the light of the spark?

The light is due to two causes. 1st. The air is intensely heated, and 2d, There are incandescent particles of the charged bodies in the path of the spark.

2. How is the latter fact shown?

If the knob of the jar be plated with silver, and that of the discharging rods with gold, the gold surface, after the discharge, is studded with silver particles, and the silver one with gold. After a discharge between substances easily pulverized, the air in the vicinity is filled with fine dust.

50. Electric Force.—1. Is there any force in the movement of these atoms?

These atoms move with sufficient force in the discharge of the Leyden jar to perforate thick card board.

2. To what is the destructive effect of lightning due?

It is not certain whether the instantaneous polarizing or neutralizing of atoms is in itself destructive. The destructive effect of lightning is due in part at least, to the infinitely rapid transportation of particles of water, air, wood or earth, and in part to the sudden expansion caused by heat.

51. Electric Sound.—1. What causes the sound which accompanies electric discharges?

The sound is due to the collapse of the air after the passage of the electrified matter through it. When lightning "strikes," the rending of bodies of wood, rock etc, adds to the sharpness and loudness of the report.

2. What causes the rolling sound of thunder?

The rolling of thunder is due to the reflection of the sound from cloud to cloud and between the earth and clouds.

52. Lightning Rods.—On what principle are lightning rods constructed?

On the principle that sharp points receive or discharge electricity with great facility and in silence.

2. How is this shown?

Let a bundle of narrow strips of tissue paper, fastened together at one end, be supported by a thick wire upon the prime conductor to represent a cloud. By their self-repellancy the strips, when charged, will stand as far apart as possible. If a sharp point be directed toward them, even at the distance of five or six feet, they at once collapse. A ball will

have no effect till brought within as many inches.

53. *Effect of Points.*—1. Illustrate a discharge from a point.

A wire terminating in a point projecting from the prime conductor will effectually prevent the accumulation of a charge.

2. How is this accounted for?

This is a necessary consequence of the self-repellancy of electricity. Let two spheres of different size on glass supports be charged to the same intensity. If now they are made to touch each other, the lesser sphere will instantly exhibit higher tension than the larger. A series of spheres diminishing in size to a point will show so great an accumulation of the force toward the smallest that the air can no longer resist the tension and the whole is dissipated.

54. *Modes of Producing Electricity.*—1. Is there any other way of exciting electricity than by friction or induction?

There are several others, each giving name to a distinct branch of the science.

2. Mention the different branches by their names.

1. FRICTIONAL	Electricity	excited by	Friction.
2. VOLTAIC	"	"	" Chemical Action.
3. THERMO-	"	"	" Heat.
4. MAGNETO-	"	"	" Magnetism.
5. ANIMAL	"	"	" Animal Organs.

55. *Static Electricity.*—What is Static Electricity?

In whatever manner it is excited, electricity may be made to abide on a surface instead of flowing along a wire. When thus captured it is termed Static (stationary) Electricity and is treated as a distinct branch of the subject?

56. *Dynamic Electricity.*—1. What is Dynamic Electricity?

When electricity moves along a wire or other conductor in the manner of a current it is called Dynamic (forceful) Electricity.

2. With which is the electric telegraph chiefly concerned?

The telegraph makes use of dynamic electricity in its ordinary operations, though static electricity is often a great disturbing force in the way of the telegraph. In ocean cables static electricity is a very important agent.

CHAPTER III.

VOLTAIC ELECTRICITY.

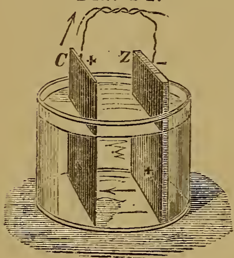
1. Volta.—1. What is the origin of the term *Voltaic?*

This term is derived from *Volta,* the name of the Italian professor who invented (A. D. 1800) what is known as the voltaic battery.

2. The Battery.—Describe the battery.

A *cell* or *element* of such a battery is a glass jar nearly filled with acidulated water, in which is placed a plate of copper, C, and another of zinc, Z, each plate terminating in a copper wire soldered to its dry end. A number of such elements connected forms a *battery.*

Fig. 14.



Voltaic Cell.

2. What are the ends of the wire called?

The free ends of the wires are termed the positive and negative *poles* or often the + and — *electrodes.*

3. What is the battery circuit?

The *circuit* consists of the zinc, the fluid, the copper and the wire; forming together a conducting path for the electricity.

4. What is it to close and break the circuit?

To *close the circuit* is to join the wires. Separating them again is called *breaking* or *opening* the circuit.

5. How long are the terminal wires?

The wires may be of any length, even to hundreds of miles, provided a sufficient number of cells be used.

6. What names are given to the plates?

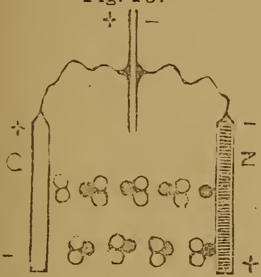
The plates are named from the electric condition of their dry ends. Thus the copper is called the positive plate and the zinc the negative plate.

NOTE.—This is given in accordance with the practice of telegraphers though usually in treatises on physics the opposite names are used.

3. Electric Conditions.—1. What is the condition of the plates before closing the circuit?

As soon as the plates are set in the liquid they become polarized; the dry end of the zinc being — and the wet end +; the copper the reverse.

Fig. 15.



2. What is the proof of this polarization?

If the electrodes are soldered to a disc of metal and the two discs placed facing each other like condensers, they exhibit very decided electric tension.

3. What is the condition of the liquid atoms?

The liquid atoms are likewise polarized. Water is a compound of two parts of hydrogen gas to one of oxygen. Each *group* of three small circles in the figure represents a *single atom* of water; the oxygen black, the hydrogen white. The *lower* line of circles exhibits the *polarization* of the atoms of water, each presenting its oxygen or + side toward the zinc and its hydrogen or — side to the copper.

4. Closing Circuit.—1. What is the effect of closing the circuit?

The *electrical* effect is to set in motion a current of electricity from the zinc to the copper in the water and from the copper over the wire to the zinc in the air.

2. What is the chemical effect?

The *chemical* result is illustrated by the *upper* line of atoms in the figure. The oxygen nearest the zinc lets go its hydrogen, which released, moves to the next group in the direction of the copper plate, takes its oxygen to form a new atom of water and sends its hydrogen onward. This process of dissolving and forming water goes through the line till the hydrogen reaches the copper where it is set free.

3. What becomes of the sulphur of the acid?

Oxygen, zinc and water unite with a portion of the sulphur to form sulphate of zinc—which is held in solution.

5. The Current.—1. In what sense is the word current employed?

Strictly speaking the current is but an infinite number of feeble discharges of electricity in constant succession. These infinitesimal discharges are taking place all over the wet

portion of the zinc and the electricity is carried with the hydrogen to the copper.

2. Is there also a negative current?

There is an equal number of discharges of negative electricity from the wet surface of the copper, carried along with the oxygen to the zinc and over the wire back to the copper.

3. Which is meant by *the current?*

When *the current* is spoken of the *positive* current is always intended, unless the word negative or the — sign accompanies it.

6. *Inconstancy of the Battery.*—1. What becomes of the free hydrogen?

A part of the hydrogen rises and escapes into the air. A part forms a film of minute bubbles all over the immersed part of the positive plate.

2. What effect has this?

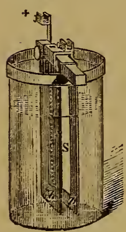
This rapidly reduces the power of the battery and renders its action unreliable.

3. Is there any way to prevent this?

Smee's battery, modeled after Volta's, employs, instead of copper, a plate of silver coated with platinum black which roughens the surface and quite prevents the film.

4. Describe Smee's battery?

Fig. 16.



Smee's battery.

The silver plate is placed between and very near two zinc plates. The three plates are suspended on a bar of varnished wood extended across the top of the jar. The zinc plates are connected at the top and furnished with a binding screw for the wire, as is also the silver.

7. *Local Action.*—1. Does any hydrogen arise from the zinc?

Nearly all zinc is impure, particles of lead, iron or other metals being mixed with it. Thus in all batteries small electric currents are set in motion on the surface of the zinc itself causing hydrogen to escape in great quantities.

2. How is this prevented?

If the zinc is first cleansed in dilute sulphuric acid and then dipped in mercury part of the zinc surface is dissolved and flows over all the impurities.

3. What is this process called?

This is called *amalgamating* the zinc and it must always be performed thoroughly with every kind of battery.

8. ***Two Fluid Batteries.***—1. Why are two fluid batteries used?

Daniell, Grove and others have made use of different fluids around the two metals in order to consume the hydrogen gas and render the battery constant.

2. Describe the Daniell's battery?

Daniell's battery has, first, the outer glass cell or jar, next, a copper cylinder open at one side and the ends, inside that a porous earthen cup, and in the cup a star shaped rod of zinc.

3. What are the liquids?

Next the zinc is sulphate of zinc and next the copper is a saturated solution of sulphate of copper.

4. What is the object of the porous cup?

The liquids must be kept separate, and yet a moist connection must be maintained between the metals or the current would be cut off.

5. How is the saturation of the liquids maintained?

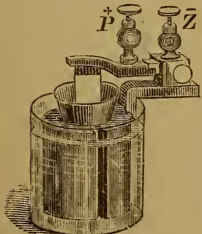
Sulphate of zinc is constantly formed inside the porous cup by the action of the battery. The sulphate of copper, however, is constantly precipitating its pure copper and sending its sulphur through the porous wall. It must, therefore, be supplied with crystals of the sulphate, kept constantly in a copper basket, in the outer jar.

6. How does Daniell's compare with Grove's battery?

Grove's battery is equally intense with this, and will supply several wires as readily as Daniell's will one.

7. Describe Grove's battery?

Fig. 17.



Grove Cell.

Grove's battery has the usual glass jar containing a mixture of eight parts of water and one of sulphuric acid. In this is a zinc cylinder open at the side and ends to admit freely the acid. Within the zinc cylinder stands a small porous cup filled even with the outer liquid, with strong nitric acid. In the nitric acid is a slip of platinum which is the positive plate. The

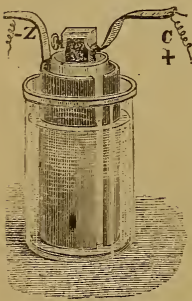
zinc has an arm carrying the binding screw for the negative electrode, and which also, in case of a single cell, sustains by an insulated support the platinum plate and screw.

7. What is the chemical process?

The strong nitric acid consumes the hydrogen gas giving off nitrous oxide fumes, which are offensive and poisonous. Bichromate potash mixed with the acid aids in keeping down the fumes.

8. What is Bunsen's battery?

Fig. 18.



Bunsen's Battery.

Bunsen's battery is like Grove's except than Bunsen uses a bar of carbon in place of the platinum. His cells are often of great size and a fluid called electropoion is substituted for nitric acid.

9. Why is this fluid better?

This gives off no fumes, is cheaper, and is nearly as effective.

10. What is its composition?

One gallon of sulphuric acid is mixed with three gallons of water. In a separate vessel five or six lbs. bi-chromate of potash should be dissolved in two gallons of boiling water and thoroughly mixed with the other.

9. *Quantity in Voltaic Electricity.*—1. In what respect does Voltaic electricity differ from Frictional?

The electricities are the same in kind. But eleetricity furnished by chemical action is of low intensity and of great quantity.

NOTE. By means, hereafter explained, Voltaic electricity may be stored up, or become static, so as to exhibit as high intensity as that produced by friction.

2. What results from this difference of intensity?

Because of its feeble intensity Voltaic electricity will traverse many miles of wire rather than pass over the hundredth of an inch of clear space or through a thin covering of silk or of varnish.

3. Illustrate the quantity obtained from a Grove cell?

Faraday found that to decompose a grain of water required three and three-fourths minutes with a Grove element. While to do the same by frictional electricity requires the charge of a Leyden battery having a metallic surface of thirty-two acres.

4. What determines the quantity?

The size of the cells determines the quantity other things being equal.

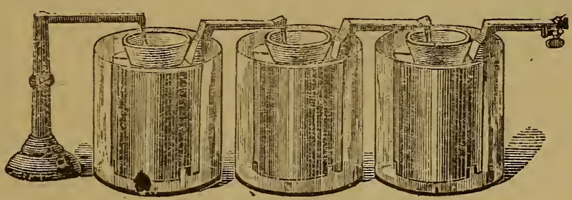
10. Quantity and Intensity Batteries.—1. What is a quantity battery?

Where great quantity is desired the zincs of different cells are connected together as one, and the positive plates are also joined. The effect is the same as increasing the size of cells.

3. What is an intensity battery?

If intensity is sought, each zinc is connected with the positive plate of the adjoining cell, the wires being attached to the zinc at one end of the series and to the positive plate at the other.

Fig. 19.



Intensity Battery. Grove.

3. What is the comparative strength and intensity of such batteries?

A battery of two cells, with the zincs joined as one, has only the intensity of one with the quantity of two. The same battery, with the zinc of one connected to the platinum of the other, has quantity one, intensity two.

4. What effects require great intensity?

An intensity current will go a greater distance, overcome greater resistance, or leap across a wider space.

5. What is accomplished by quantity?

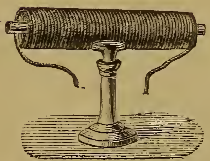
Chemical effects, heating, lighting and magnetizing power depends more upon quantity; though both intensity and quantity contribute to these results.

CHAPTER IV.

ELECTRO-MAGNETISM.

1. *The Magnet.*—1. What is an electro-magnet?

Fig. 20.



Electro-Magnet.

A bar of iron subjected to the influence of a voltaic current becomes polarized by induction and is hence called an electro-magnet.

2. *The Helix.*—1. How is the current applied?

The wire from the battery is coiled spirally around the bar so that the current in passing over the wire moves at right angles to the bar.

2. Does the wire touch the bar?

No. The wire is *insulated* by being covered with silk and varnish, and the opening may be larger than the bar, though the nearer the wire is to it the more powerful the induction.

3. What is this apparatus called?

The coil of wire with or without the bar is called a *helix*. If the spiral turns from *left over to right*, as in the figure, it is a *right-handed* helix. If it turns in the opposite direction it is a *left-handed* helix.

3. *Relation of Poles to the Current.*—1. What determines the direction of the poles of the electro-magnet?

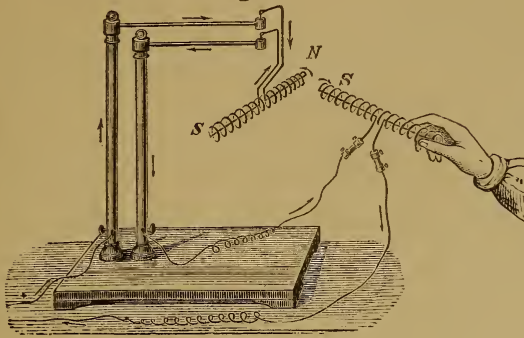
The direction of the pole depends upon the direction of the current. In the figure the current enters the helix near **S**.

2. What is the rule?

The south pole will always be at the end where the current enters if the helix is right-handed. The reverse is true if the helix is left-handed.

4. ***The Solenoid.***—1. What is a solenoid?

Fig. 21.



The Solenoid.

This word means a *tubular magnet.* It is technically applied to a helix whose ends are bent back through the coil to the middle, where they emerge without contact in any part. Two such are seen in the annexed figure.

2. Why is it called a magnet?

Such a helix is found to possess all the properties of a magnet. If one solenoid be delicately suspended, as in the figure, it will stand in the magnetic meridian, and if another be used as an analyzer it will alternately attract or repel it precisely as a magnet will act on a needle. (*p.* 2.)

3. How will the solenoid affect a bar placed within it?

A bar placed in the solenoid becomes a magnet whose poles are the same as those of the solenoid itself.

4. What may be used as an analyzer of the solenoid?

A steel magnet may take the place of either solenoid, and will exhibit the same result.

5. ***Ampere's Theory.***—1. State Ampere's two postulates?

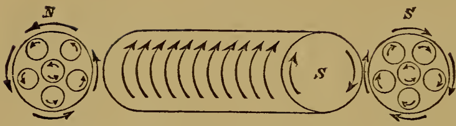
A helix traversed by the current is a magnet, the positions of whose poles depend on the direction of the current. Conversely, a magnet may be conceived to owe its properties to currents of electricity which traverse it.

2. What is Ampere's theory of magnetism?

Ampere's theory is that the atoms of magnetic bodies are continuously traversed by currents of electricity in different directions; that to *magnetize* a body is simply to place these *currents parallel* to each other. When all are parallel the magnet is *saturated.*

3. How does the solenoid explain this?

Fig. 22.



The single current of the solenoid is equivalent to all these infinitesimal parallel currents.

4. How do the currents at the poles differ?

If the currents were visible, on looking at the **N** end of a magnet they would be seen moving from right over to left. And if the magnet were also transparent one could look down the length of it and *all* the currents would be seen to move in the same way. But on inverting it and looking at the **S** end the currents appear to move from left over to right as in the figure.

5. On this theory why do opposite poles attract each other?

The currents of opposite poles when placed together move in the same direction, as if the two magnets were but the continuation of one magnet. Like poles repel because their currents oppose each other.

6. *Permanency of Electro-magnets.*—1. How long will the electro-magnet retain its force?

Mr. Elisha Gray's experiments have shown that a pure soft iron bar may be magnetized and demagnetized many thousand times in a second.

2. What is Gray's experiment?

He uses a tuning fork, to one leg of which a fine platinum spring is soldered, to open and close the circuit. To the end of the electro-magnet a thin plate of metal is screwed. The vibrations of this plate will correspond to the number of times the iron is magnetized and demagnetized. They are proved to be as rapid as those of the tuning fork by the identity in pitch of the sound produced.

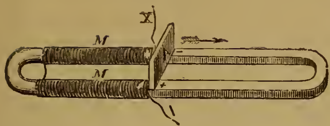
3. Can permanent magnets be made by the current?

If there is any hardness about the iron from hammering, filing etc., a *residual* magnetism is developed. And if a steel bar be introduced into the helix, a permanent magnet results.

4. What if the bar is bent or too large for the helix?

To magnetize a steel **U** place it end to end with the poles of a **U** electro-magnet, move a piece of soft iron back and forth along the steel never beyond the bend. Take it off at

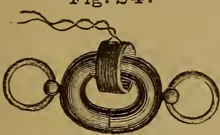
Fig. 23.



the center. Turn the system over without separating and operate as before. Open the circuit before removing the steel.

7. Power of the Electro-magnet.—1. What apparatus exhibits the power of the electro-magnet?

Fig. 24.

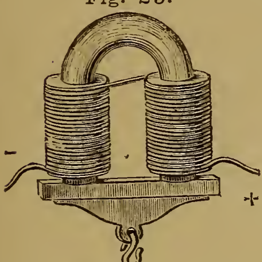


Ring and Helix.

A thick ring of soft iron is cut into semicircular halves and a small helix is made to fit loosely on one of them. A current through the helix will cause the halves to adhere with great force.

8. Form.—1. What form is favorable for strength?

Fig. 25.



Electro-Magnet. Com. Form.

In general the **U** form is best. An arrangement like that in the figure will sustain hundreds of pounds.

For many purposes two spools or bobbins of iron wound with insulated wire, and screwed fast to a straight piece of iron at one end is the best form.

9. Electro Motors.—1. Define electromotors.

An engine driven by the force of an electro-magnet is called an electromotor.

2. Why are not such machines in common use?

The expense of this force is many times that of steam, though it is more compact. A small fraction only of the actual force generated has ever yet been utilized.

10. Practical Uses.—1. What is the most important application of the force?

The value which far transcends all others in importance is found in its applicability to the electric telegraph.

2. What minor uses may be mentioned?

It is also employed for burglar and fire alarms, hotel annunciators, the recording of minutes and exact dates of astronomical or other events; nearly all of these are modifications of the telegraph.

11. Deflection of the Needle.—1. What was Oersted's discovery?

Oersted, in 1819, discovered that a voltaic current passing northward over a magnetic needle will cause its **N** pole to

turn west. If it pass northward under the needle the **N** pole will turn east.

2. What is the law of the movement?

Ampere gave the following rule to aid the memory;

Suppose a metallic human figure be made a part of the circuit, and so placed that the current shall enter at his feet and leave by his head, then if his face be always toward the needle the **N** pole will be deflected toward his left.

3. What if the current go northward over the needle and return under it?

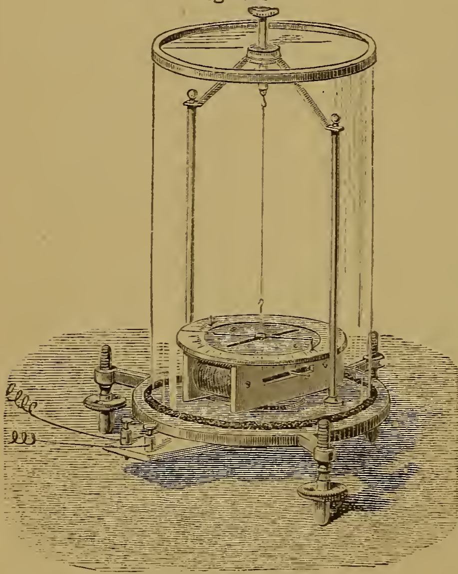
Passing the current *around* the needle in the direction of its length doubles its power of deflecting the needle.

4. Is there any limit to this mode of increasing the power?

The power increases with the number of convolutions of the wire, but diminishes with its distance from the core.

12. The Galvanometer.—1. What application is made of this principle?

Fig. 26.



The Galvanometer.

This principle is used in the construction of the galvanometer, an instrument for detecting and measuring very feeble currents.

2. Describe it.

An astatic system (Sec. 12; question 5; chap. I,) is suspended by a very fine platinum wire is a glass case. A flat helix of many convolutions of the finest insulated copper wire is supported on a wooden or ebonite frame so that the lower needle is enclosed within it and can turn freely. A card under the upper needle is graduated to show the amount of motion. The wires of the helix terminate in the binding screws. The instrument is provided with leveling screws and the helix

may be turned so as to place its wires parallel to any position of the needle.

3. What are some of the uses to which it is applied?

The special use of the galvanometer is to reveal the presence of a feeble current and to measure its force. It may be employed to detect an escape or waste. The receiving instrument of the ocean telegraph is a modified form of the galvanometer.

CHAPTER V.

INDUCED CURRENTS.

1. *Electro Magnetism.*—1. What has already been observed respecting the helix?

We have seen (Sec. 4 Chapter IV) that the *helix itself* possesses the properties of a *magnet*, having polarity and the power of repulsion as well as attraction.

2. What is now proposed?

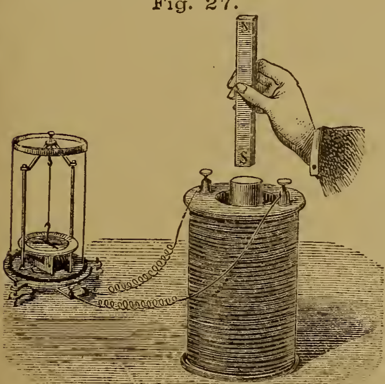
We are now with the galvanometer, to compare the helix and magnet still further and identify their characteristics more fully.

3. What was Faraday's reasoning?

"If electric currents," said Faraday, "induce magnetism then magnetism should induce currents." Experiment proves this true.

4. Describe the experiment?

Fig. 27.



Currents from a Magnet.

Let a helix, with or without a soft iron core, have its terminal wires screwed into the binding posts of a galvanometer. Next let one pole of a steel magnet move to and from the end of the helix as in Fig. 27. During this motion the needle of the galvanometer will vibrate.

5. What is the direction of this current?

While the magnet is approaching, the current will

have the same direction as the Amperean currents of the magnet. When the magnet recedes the current is reversed.

6. What if the magnet is held still?

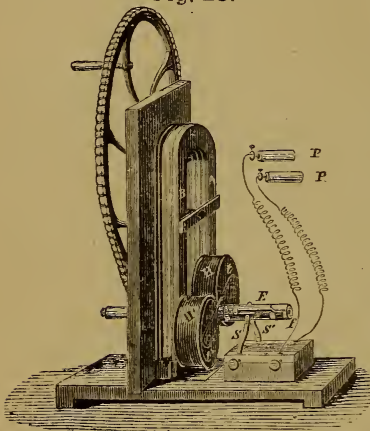
When the motion ceases the current ceases, however near the magnet may be to the helix. The more rapid the motion the stronger the current.

7. What is the effect of suddenly reversing the poles of the magnet?

Reversing the magnet will cause an equally sudden reversal of the current, as this implies the receding and approach of each pole alternately.

8. What machine is constructed on this principle?

Fig. 28.



Clark's Machine.

In Clark's magneto-electrio machine this sudden reversal is affected by causing two helices with their cores to revolve in front of a permanent horse-shoe magnet of great power. The change of polarity in the core causes a succession of induced currents in the helices. By means of a commutator **E S**, Fig. 28, the currents are made finally to flow in a single direction.

9. What is the essential point in the production of induced currents?

The essential condition of producing the currents is the *constantly varying intensity* of inductive influence.

10. How is this accounted for?

There is here no infinite succession of electric discharges such as the dissolution of zinc in a battery furnishes. The induced *current* so called is but a *single wave* of polarization that traverses the wire and ceases. But every movement which brings the magnet nearer, by increasing the *amount* of polarization starts a new wave. Withdrawing the magnet releases the tension and allows the return wave of neutralization.

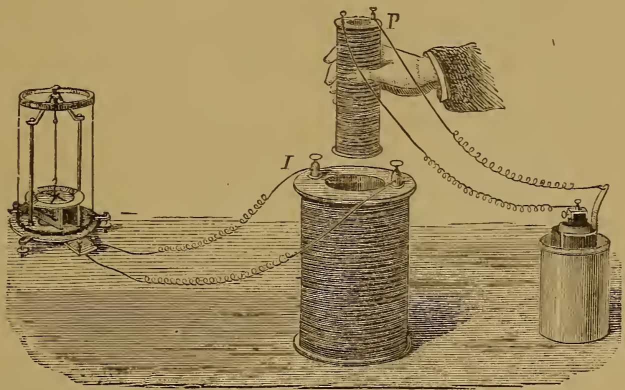
2. ***Primary and Secondary Currents.***—1. What are secondary currents?

A current is called *secondary* when it is induced in an insulated wire by *another current* called its *primary*.

2. What is the arrangement of the wires?

The apparatus for secondary currents is exactly the same as for electro-magnetic currents except that a small helix connected with a Bunsen element takes the place of a magnet, as in Fig. 29, **P** is the *primary* helix and **I** the *secondary*.

Fig. 29.



3. What is characteristic of this current?

The secondary current is far more intense than the primary but depends for its existence on a constant movement of the primary helix, or else a constantly varying power of the battery.

4. What arrangement will give a strong secondary current?

Let the primary helix be placed inside the secondary fitting as closely as is consistent with the best insulation, and let a core of soft iron be inserted in the primary helix. As this precludes any movement of the primary, *variation* of battery *intensity* is employed instead.

5. How is the greatest possible variation secured?

Rapidly opening and closing the circuit is of course the extreme of variation and gives the most intense secondary currents. It is accomplished by drawing one electrode quickly along a coarse file.

6. What is the direction and duration of the secondary current?

The secondary current thus produced is an instantaneous shock or wave merely. Its direction as shown by the galvanometer is the *reverse* of the primary at the instant of *closing* the circuit and the same as the primary on opening.

3. Currents of the Third and Higher Order.—1. What are the currents of the third order?

The secondary current, notwithstanding its brief duration, is capable of inducing a third current in a helix near it, and this a fourth and so on. Currents as high as the ninth order have been made.

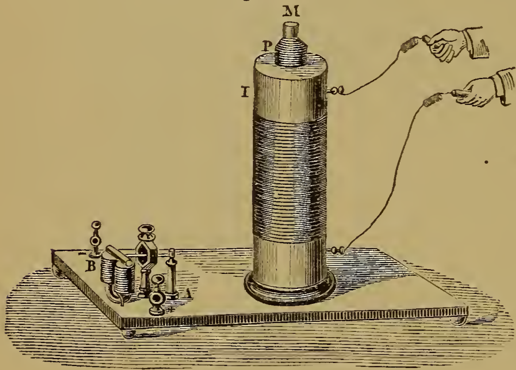
4. The Extra Current.—1. What is the extra current?

While the primary wave is traversing one part of a helix it excites an induced current in the *adjacent parts of the same helix;* these are called *extra currents* to distinguish them from currents which require a second helix.

5. The Inductorium.—1. What is the Inductorium?

This is a compact arrangement of powerful helices for rendering the electricity of the induced current *static* and of as high intensity as that of the best friction machines.

Fig. 30.



The Inductorium.

2. What are the different parts of the apparatus?

An inner primary helix, **P**, of coarse copper wire two or three layers deep surrounds a core of soft iron parallel wires, **M.** A glass or ebonite spool **I** surrounds the primary coil, containing in Ritchie's coils, from five to eighty *miles* of the finest copper, insulated wire. The basement is filled with many square feet of tin foil between insulating sheets of oiled silk.

3. What is the use of the tin foil layers?

These have the effect of absorbing the extra current which is a disturbing force.

4. At what points does the electricity appear?

The terminals of the outer helix are the electrodes of the secondary current. These may be connected with handles as in the figure, or employed in any way to give direction to the discharge.

5. How large a battery is required?

With a secondary helix of fifteen miles of wire and a battery of eight Bunsen cells most beautiful and brilliant effects are produced.

6. How is the circuit opened and closed?

The interruption of the current is often made by a toothed wheel turned by a small crank against a break-piece.

In the figure an automatic interrupter is seen at **B**. The current on its way to the primary helix operates a small electro-magnet; this draws down an armature and breaks the circuit. A spring closes it again as soon as **B** ceases to be a magnet.

7. What caution is to be observed?

The shock of such a charge would be serious if not fatal.

A Leyden jar is fully charged with a single break of the circuit.

CHAPTER VI.

ELECTRIC TELEGRAPH.

1. What is a telegraph?

Any instrument by which ideas are directly transmitted a great distance is a telegraph, (*tele* far, *grapho* to write.)

2. What are the old forms?

Thus signal fires, rockets, colored lights, bells and guns, and sometimes figures and words, to be read by telescopes have long been in use.

The army and navy signals are extremely ingenious and must continue in use at sea.

3. What is peculiar to these methods?

In all these the operator makes only *large movements in his own neighborhood*, to be seen or heard by a distant observer.

4. How are they limited?

They are limited to comparatively short distances and few expressions.

5. What power does the electro-magnet furnish?

The electro-magnet furnishes that essential requisite of a complete telegraph, the *power to move matter which is far from the operator* at will, in at least two directions.

6. What advantage does this give to the electric telegraph?

This enables us to construct an instrument which shall express every shade of thought at any distance, over every variety of surface and at all seasons, and yet occupy but an inappreciable time in the transmission.

1. *History.*—1. With whom did the idea originate?

It is not known who first suggested the idea. It was entertained as soon as electricity became a science.

2. What were the practical measures adopted for its use?

1740. Franklin invented the cylinder machine for frictional electricity. He sent a wave two miles and killed an animal.

1747. Bishop Watson, of London, sent a signal two miles, at Shooter's hill, using the Leyden jar.

1753. Sir Francis Roland published his system. He sent messages 8 miles using synchronous revolving dials with letters on them, and pith ball electroscopes.

1774. Lesage, at Geneva, erected a telegraph with twenty-four wires, one for each letter. The signal was a lettered pith ball.

1819. Oersted discovered the power of the current to deflect the needle.

1820. Ampere proposed to letter twenty-four needles and move each by a separate voltaic current; *the first use of* chemical electricity for this purpose.

1833. Weber and Gauss, of Prussia, simplified this by using fewer wires and needles.

1834. Professor Henry, of Washington, sent messages three miles using the armature of an electro-magnet to give the signals.

1837. Prof. Morse procured his patent for the Morse alphabet and register.

In the same year Steinheil, in Germany, and Wheatestone and Cooke, in England, took out patents for their systems, still in use, but rapidly giving place to Morse's system.

2. *The Telephone.*

In 1873 Elisha Gray, of Chicago, substituted for the ordinary vibrator of a small inductive coil, a slip of steel so thin as

to give a clear musical tone, his object being to transmit the vibration over the wires of the secondary helix and reproduce the tone at a distant station. The success of his experiment was complete. By inserting the common telegraph key in the primary coil the duration of this musical tone could be controlled at pleasure. The receiving instrument at first was a thin plate of German silver attached to a ground wire and stretched across the bridge of a violin to increase its sonorous qualities. The operator at the receiving end took the line wire in one hand and moved the fingers of the other gently over the plate, when a clear sweet note came out, of the same pitch as the steel vibrator at the other end. It was found that animal tissues were thus perfectly responsive to the vibrations.

Mr. Gray soon after made use of the primary current alone, producing the necessary interruptions by vibrating springs. For a receiver he substituted a single long helix with a core of soft iron, to one end of which was screwed fast the sounding plate. A soft iron rod lengthens every time it becomes a magnet, and shortens again when the circuit opens. In this way the plate is shaken and the tone comes out. A recent improvement in the transmitter is made by using the key to strike a tuning fork to which a delicate platinum spring is soldered. This spring is the interrupter. Letting up the key damps or stops the vibrations of the fork. The present receiver is a fine steel ribbon stretched like a bow string across a small frame and placed like the armature of an electro-magnet, only not near enough to touch. The ribbon is tuned to the pitch of the transmitting fork and responds clearly and beautifully to the attractions and repulsions of the magnet.

On Mr. Gray's recent visit to Europe the invention was thoroughly examined and approved by Prof. Tyndall and others of the highest authority, as it had already been in this country. It was found to operate through the Atlantic Cable with the same facility as over land.

The commercial value of this invention lies in the fact that by branching the line wire at the ends, any number of trans

mitters and receivers can operate *over the same line*, each being on a different pitch and not interfering with the others.

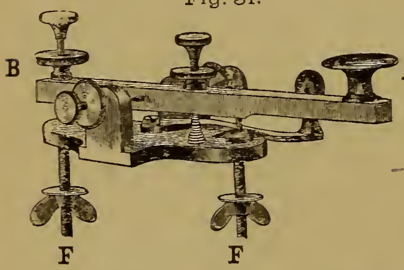
By combining the transmitters with a single instrument melodies and even harmonies may be sent as easily as a single note. Mr. Gray received tunes in Washington which were transmitted from Chicago. This instrument seems destined to work an entire revolution in telegraphy as it multiplies the capacity of every wire and every cable many fold. It may also possibly lead to a marked simplification of the telegraphic alphabet. The sustained tone renders possible the use of rythmical symbols so that a single movement may stand for a number of different letters, and no letter need have more than two characters.

3. ***Morse Electric Telegraph.***—1. What is the Morse Telegraphic system?

The Morse system permanently records a message by the power of the electro-magnet on a narrow strip of paper. The Morse alphabet (see frontispiece) being constructed to require only dots and straight marks.

2. Describe the key.

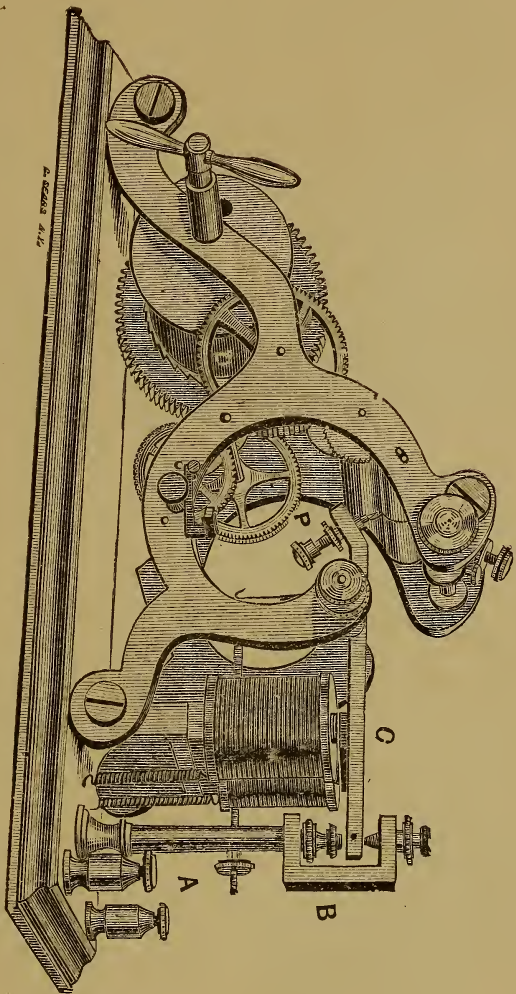
Fig. 31.



The Morse key consists of a brass lever **A B** about five inches long hung upon a steel arbor between set screws. The lever is connected with one electrode of the battery. It is capable of vertical motion only through a very small space. An ebonite button at **A** is used to depress the lever till it strikes the small platinum anvil, which is the opposite electrode, and insulated from the frame. This closes the circuit. A spring raises it when the pressure is withdrawn thus opening the circuit. When the key is not in use, the *circuit closer* is pushed against the anvil. The screws **F F** fasten the key to the table.

3. Describe the register.

An electro-magnet **M** is placed near one end with terminal


P
C
A
B

wires attached to binding screws at **A**. Above the electro-magnet is the armature **C** which carries a lever having a small vertical motion between set screws at **B**. The other end of the lever carries a steel point **P**. A strip of paper is carried over the steel point and between two grooved rollers by clock work. The clock is propelled by weights attached to the drum **D**.

4. What is the operation of the register?

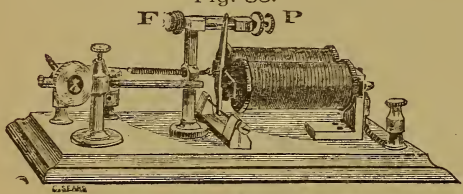
When the circuit is closed by the distant operator the armature is attracted by the magnet **M** and the style **P** is pressed against the paper. The groove allows a slight line to be thus embossed upon the moving paper, its length being at the will of the operator.

5. What is the relay magnet?

As the current on a line of more than 20 or 30 miles becomes too feeble to work the register, it is passed through a pair of helices called a relay magnet whose office it is to open and close the circuit of a local battery at the receiving station. The local battery operates the register.

6. What is its construction?

Fig. 33.

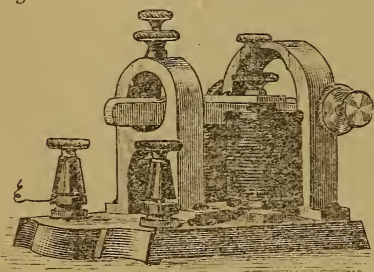


Relay Magnet.

It is made of very fine wire (30 to 36) very long and very closely wound. The armature in front of the helices carries an upright lever. One electrode of the local battery enters this lever, the other, after passing the register enters the frame **F** which has a platinum point at **P**. When the armature is attracted the local circuit is closed. A spring withdraws the armature when the line current is broken.

Fig. 34.

7. What is the sounder?



Local Sounder.

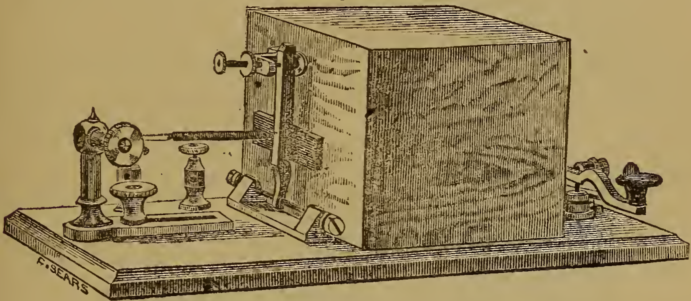
The sounder is an instrument for reading a message by the ear. It is an electro-magnet with armature and lever like the register but without the recording apparatus. This in many cases supercedes the necesity of a register or of a local battery. A current too fee-

ble to work the register is often ample for the lighter movement of the sounder.

8. What is the box sounder?

The box sounder is designed to give resonance to the sound of the lever. Its construction is like that of a relay except that the magnet is enclosed in a fine mahogany case. It is used principally as a main-line sounder, and also as a relay.

Fig. 35.

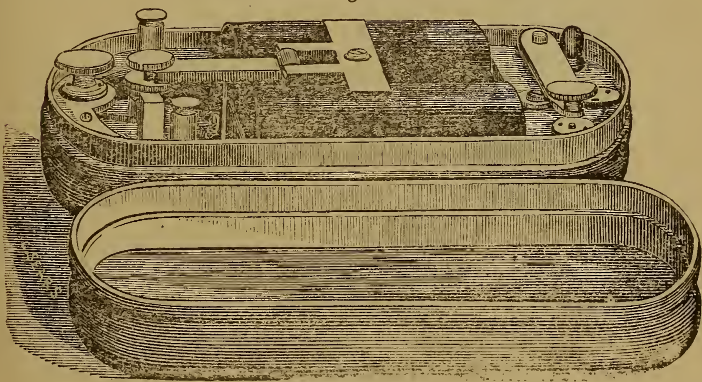


Box Sounder, or Relay.

9. Describe the pocket relay.

In the pocket relay the lever is brought down so as to pack in a case. It is a main-line sounder and is used by line repairers.

Fig. 36.



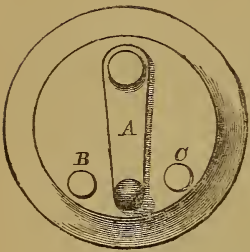
Pocket Relay.

10. What is the switch?

The switch, or commutator is a contrivance for quickly changing the current and for coupling or dividing circuits.

11. Describe the ground switch?

Fig. 37.



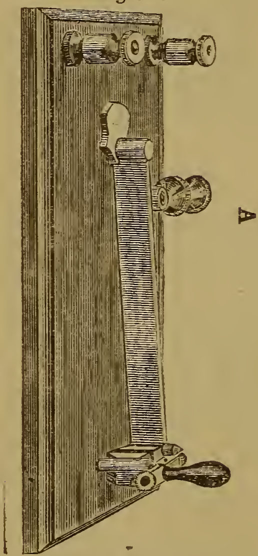
Ground Switch.

The ground switch has a lever **A** attached to a wire leading to the earth. Two studs **B** and **C** connect with the line wire on either side of the instruments. By means of an ebonite button the lever **A** may be used to connect either line with the ground.

12. The button switch?

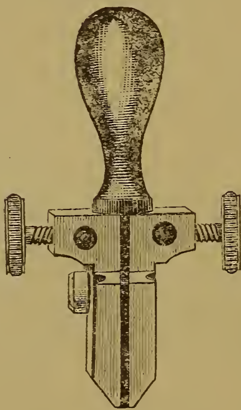
In the button switch the ground wire is wanting and the lever may unite **B** and **C**.

Fig 38.



The Plug Switch.

Fig. 39.



The Plug.

The plug switch is a stout brass spring placed firmly against a stationary pin whose pressure is regulated by a set-screw **A**. The binding screws at the top of the figure connect with the main-line.

The wedge or plug consist of twopieces of brass insulated from each other by bone rubber, and furnished with avulcanite handle, as shown in fig. 39, which shows it of actual size

The wires leading to the relay are attached to this plug and firmly held by binding screws.

When the plug is inserted on the switch, as represented in fig. 38, the main current is diverted through the relay, but it cannot be interrupted or "broken" by inserting or withdrawing the wedge; in the latter instance the spring instantly closes the circuit when the wedge is withdrawn.

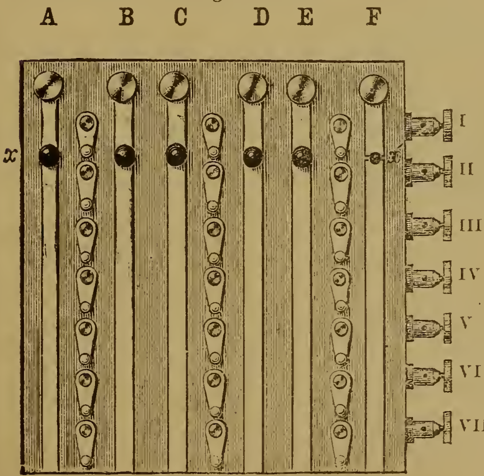
14. What is the Culgan switch?

The Culgan switch is designed for offices which many lines enter. Straps of brass **A B C D E F**, Fig. 40, are placed vertically on a varnished plank, or other non-conductor, and furnished with binding screws at the top for the line wires. Rows of short buttons with ebonite handles hang between the straps and have metallic connection with the binding screws, I, II, III, IV, V, VI, VII, at the side. The upright straps are all cut in two in the line *x x'* and joined again by pushing a brass peg between the ends. One is seen withdrawn at *X*.

It may be seen by a slight inspection that any of the upper binding screws as **A** can be connected with any of those at the side as V by turning the appropriate button.

15. How many wires would the board in the figure accommodate?

Fig. 40.



The Culgan Switch.

At a way station a switch with six straps and seven horizontal wires would provide for *three through lines and three instruments.*

16. What would be the method?

Suppose three wires from the east terminate in the binding screws **A**, **B**, **C**, and three from the west in **D**, **E**,**F**; **A** and **D**,**B** and **E**, **C** and **F** being opposite electrodes.

Let instrument No. 1, be connected with the side srews I and II; Inst. No. 2 with III and IV; and No. 3 with V and VI. The ground wire is at VII.

If we wish the lines, whose electrodes are **A** and **D** to be shunted through instrument No. 1, turn the buttons so as to connect **A** with I and **D** with II.

If the line is to go through direct, without shunting, simply connect **A** and **D** to the same horizontal wire.

17. For how many wires at a terminal station would this provide?

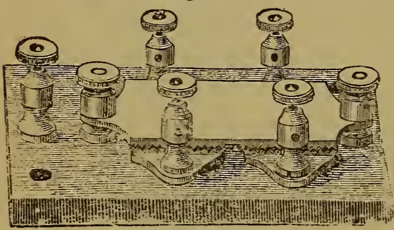
This switch would provide for six wires at a terminal station.

It is obvious that any line may be shunted through a *loop* as well as through an instrument by the same arrangement and the switch board may be of any size.

18. What is the lightning arrester?

The danger of injury to instruments and operators from lightning, has led to the device called the arrester. As static electricity prefers a short route over a poor conductor to a long one over a good conductor, it can easily be diverted from the offices as follows:

Fig. 41.



Arrester.

A plate of brass five or six inches long is attached to the ground wire. On this is a sheet of varnished silk and above the silk other plates of brass attached to the line wires. The lightning easily passes into the lower plate and thus to the ground, while the voltaic current will not go through the silk.

19. Describe Bradley's arrester?

Bradley substitutes air for the varnished silk and has sharp points attached to each plate reaching nearly over to the other plate. This is a very effective instrument and is used also for a ground or a shunting switch.

20. What are repeaters?

When the distance from the sending to the receiving office is great the current does not go through, but is employed at

way stations to open and close the circuit of a second battery which continues the message to a third and so on without rewriting. The apparatus for this is called a repeater. It is nearly the same in form as a relay or sounder.

21. How far may messages be sent by this means?

There is no practical limit to the distance. Messages have been sent from Harvard Coll. to San Francisco and back to the same office with the view of ascertaining the speed of transmission. The distance in this case, reckoning the length of wire in the repeater as well as in the line wire, was upwards of ten thousand miles which occupied about seven-tenths of a second.

22. For what other purpose is the repeater used?

The repeater is valuable for transmitting news simultaneously over different branch lines.

PART SECOND.

PRACTICAL TELEGRAPHY.

CHAPTER I.

THE BATTERY.

Note. Attention is given in this chapter to the four forms most in use the Daniell, the Grove, the Bunsen and the Callaud batteries; the latter, a modification of Daniell's, is rapidly coming into favor.

1. *The care of Ba teries.*—1. Why does the battery first claim attention?

As the battery is the source of power it is of the highest importance that every thing pertaining to it be kept in most perfect working order. A filthy, wet, or leaky battery is not only extremely untidy' but extremely wasteful and dangerous to health. It is also an excellent test of the general thoroughness and trustworthiness of the operator.

2. *Daniell's Battery.*—1. How is Daniell's battery set up?

If the battery is to be used at once, dilute sulphate of zinc should be used for the porous cup and a perfectly saturated solution of sulphate of copper in the jar. The zinc is to be amalgamated and inserted in the porous cup. The liquids may then be poured in till they are at the same level and the jar nearly full.

2. What attention do the connections need?

The connections are to be *filed* bright and all dust removed. Sand paper or emery are apt to leave non-conducting particles on the metals and are to be discarded. Connect the zinc of one cell to the copper of the next through the battery. The *current* always starts from the copper.

3. The blue vitriol?

The sulphate of copper is continually disappearing and when it is gone the current stops, also sulphate of zinc comes through the porous cup. The perforated cup or basket attached to the copper must always be supplied with pulverized vitriol.

4. Care of the sulphate of zinc?

The action of the battery produces sulphate of zinc and when the solution in the porous cup is overcharged it crystallizes on the zinc and destroys the current. Part of it should occasionally be taken from the porous cup and its place supplied with water.

5. How often do the zincs need cleaning?

Once in two weeks the zincs should be taken out scraped and cleaned with a stiff brush, and amalgamated. Save a third of the clear part of the liquid to return to the porous cup, fill up with water.

6. Care of the porous cup?

The porous cup is to be thoroughly washed. See that no cracked cup is replaced, as it occasions great waste of power. To prevent as much as possible the copper deposite let the zinc not touch the cup. The copper deposite is not to be wasted when the cups are used up.

7. How are the copper cylinders kept?

The coppers should be cleaned of all deposites once in three months. They will probably last a year.

8. Care of the jars?

New jars unless they are of glass should be saturated with paraffine. The edges must be wiped with a damp cloth to remove crystals, otherwise insulation is destroyed by moisture between the jars and great waste of power results. All dirt and rust and moisture must be kept away from the floor on which the jars rest. When the jars are moved dry wood ashes should be used to clean the shelf or floor where they stood.

9. What does the Callaud Battery require?

The Callaud battery *dispenses with the porous cup* while still using two fluids. It is constructed on the principle that sulphate of copper is heavier than sulphate of zinc.

10. How are the metals placed?

The copper, with its sulphate and a good supply of crystal in powder, is placed at the bottom of the glass cell. The zinc in form of a wheel lies at the top of the fluid immersed in sulphate of zinc and supported by a frame across the top of the jar. A gutta-percha-covered wire leads up from the copper to furnish the positive electrode.

11. What other battery is similar?

Hill's battery differs from this only in the shape of the metals. These are much used in telegraphy.

These batteries must be placed where there is the *least possible jar* as any disturbance mixes the liquids and destroys the power of the battery.

3. *Care of the Grove batterry.*—1. How is the Grove battery set up?

For long use, set the tumblers in position, and fill them half full of the solution. One part of sulphuric acid to twenty-five of water by measure, thoroughly mixed.

Next set in the zincs to which the platinum strips are soldered, with arms to one side of the line of cells.

Place the porous cup inside the zincs and fill them with strong nitric acid to the level of the top of the zincs. Lastly turn the arms and immerse the platinum strips in the acid.

2. What if several wires are worked by one battery?

If four or six wires are worked the sulphuric acid should be in a little greater proportion say one part to twenty of water. A single wire is worked by one to thirty.

3. How often is it renewed?

A Grove battery in constant use should be taken down every night, the nitric acid put away in stoppered bottles and the zincs placed inverted in acidulated water. In the morning the zincs are rubbed with a brush and, unless bright like silver, moistened with a few drops of mercury which is rubbed evenly over them inside and out.

4. How often are the acids renewed?

Add one part in ten of nitric acid every morning. Renew the sulphuric acid entirely once a week.

5. How long will such a battery last?

The platinum strips last till they are broken up by careless handling. The zincs dissolve or become perforated and worthless in about three months.

A warm situation promotes dryness as well as chemical activity.

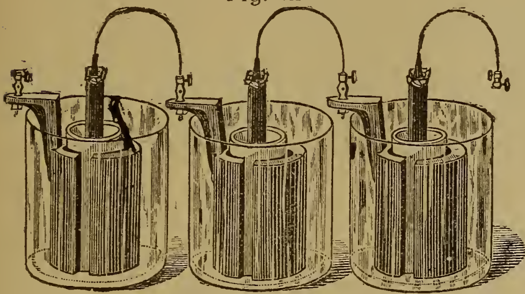
4. *The Carbon Battery.*—(see page 32.) 1. What caution is to be observed in setting up a Carbon battery?

As carbon is a poor conductor of electricity extra care should be used to have a broad surface contact with the metal

and to have the clamps screwed up. The zincs require the same treatment as for the Grove battery. New zincs must be thoroughly amalgamated a second time after three days use.

2. How often does the battery need cleaning?

Fig. 42



Carbon Battery.

This battery needs to be taken apart once in two weeks, when the zincs should be brushed and amalgamated and the carbon soaked in clear water. Take care that no green rust is left between the carbon and its metal.

3. Which battery is most useful?

When several lines are to be worked by one battery, Grove's is far the most effective, working twice as many wires as the Carbon battery. Yet it is no more intense. Fifty Grove cells will send the current no farther that fifty Bunsen cells.

4. Which is most expensive?

The whole expense of purchasing and running the Grove battery is more than three times that of the Bunsen battery. It is cheaper, therefore to supply *two sets* of the latter, each working three lines, than to have *one* of the Grove battery working six lines.

5. How often does the electropoin fluid need renewal?

One third of the fluid in the porous cup if the battery is in constant use, needs to be withdrawn, by means of an ebonite pump or syringe, every day, and its place supplied with new.

6. The zincs?

The zincs with proper care last a year and sometimes a year and a quarter.

7. Should the jars of a battery be insulated from each other?

It is absolutely essential to insulate all the jars *from each*

other and *from the ground.* Glass jars if *kept dry* insulate themselves. Dry stone-ware jars saturated with parafine need no further insulation. Ordinary stone-ware jars continually exude moisture and must have separate insulation. A small plate of crockery ware inverted over a block an inch thick makes an excellent insulating support. A glass plate with perpendicular rim is the best.

CHAPTER II.

CARE OF INSTRUMENTS.

4. ***The Key.***—1. What directions are given for the key?

1st. The connections must be kept perfect, else leakage and loss result.

2d. When the key is not in use the circuit is always to be closed, otherwise the line is inoperative beyond the station where the carelessness occurs.

3d. Examine occasionlly the platinum points of the anvil and lever to see that no corrosion or dirt injures their perfect contact.

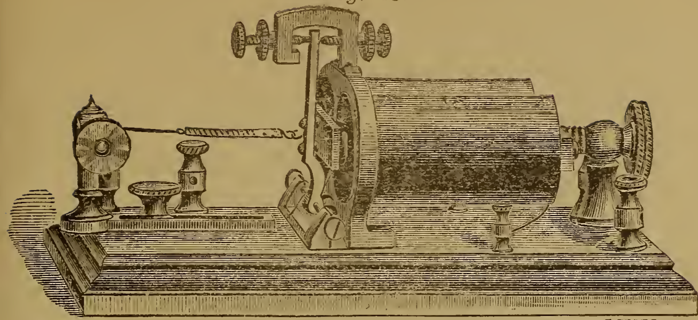
4th. Wipe off all moisture or dirt about the circuit closer which might cause partial connection when the circuit is open and make the key stick.

2. ***The Relay.*** 1. What directions for the relay?

1st. Examine the platinum points, as for the key, and remove corrosion with a very fine file used carefully, for platinum is worth more than its weight in gold.

2d. If the relay is unsteady or confused adjust the springs of the armature by means of its thumb-screw.

Fig. 43.



Relay.

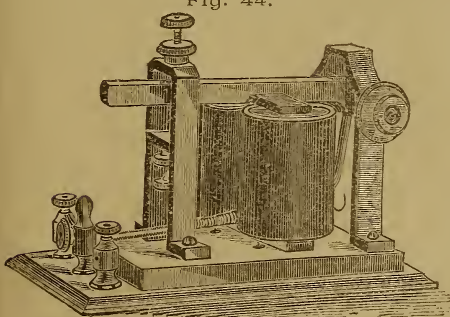
In many instruments the adjustment is made by moving the cores of the magnet as in the figure.

3d. In rainy or very changeable weather it is necessary to attend to this adjustment with the nicest care and observation, separating the cores from the armature, or the opposite, to make sure whether the line is in use by other offices.

4th. The key should *never* be opened till this point is settled.

5. The Sounder.—1. What care does the sounder require?

Fig. 44.



Local Sounder.

1st. Adjust the spring of the sounder lever so that the back stroke shall be lighter than the direct stroke, caused by closing the circuit.

2d. If the local sounder does not operate when the relay does, the fault must be in the local circuit. All the local connections must then be examined till the cause of the mischief is discovered.

5. The Register.—To what defects is the action of the register liable?

1st. The *paper may run crooked.* This can be remedied by adjusting the pressure on the upper roller. The pressure on the two ends must be equal.

2d. The *paper may stick* in the guides. This is probably

the fault of the paper, which is not cut of uniform width. If the guides are adjustable separate them slightly. Otherwise remove the paper and put in new.

3d. The *armature may stick.* This happens when the armature is allowed to touch the cores of the electro-magnet. It is remedied by adjusting screws at the end of the lever. The lever should have barely motion enough to let the style clear the paper and go into the grove without scratching against the roller.

4th. The marks made by the style may be indistinct or of bad shape. See that the pivot screws are adjusted as to give the lever no side play and that the style stands exactly opposite the grove.

6. *The Arrester.*—1. To what injuries is the lightning arrester su ject?

1st. The common form of arrester is liable to dampness between the plates as paper is often used instead of varnished silk. It should be often taken apart and examined to prevent serious escapes of the current from this cause.

2d. A discharge of lightning through the arrester will often carbonize the paper or silk, thus rendering it a conductor; or may even fuse the plates together, making a perfect escape for the voltaic current. It should never be left without inspection after a storm.

Bradley's arrester, manufactured by L. G. Tillotson & Co. New York, is subject to neither of these mischances.

7. *The Repeater.*—1. What care does the repeater need?

1st. The same cautions that apply to the relay are applicable also to the repeater.

2d. Beside this, it is to be remembered that as it takes time for the repeater lever to move, the duration of the current sent on by it, is *shorter* than that which it has received. The lever should therefore have the least motion that will answer.

2. What caution is necessary in *using* repeaters?

In sending a message through repeaters, especially if there are several, more time than usual should be allowed for contact by the key, both in making dots and dashes, and as much less time for spaces.

CHAPTER III.

TELEGRAPHIC MANIPULATION.

1. *Management of the Key.*—1. What hints are given for using the key?

1st. The ends of the first and second fingers should rest upon the button with the thumb underneath. The grasp should be firm but not strained.

2d. The movement is made by the whole hand and fore-arm, not the fingers.

3d. The up stroke is not less deserving of attention than the down stroke; both should be decisively made, but with sufficient force to ensure perfect contact.

4th. Write slowly at first, noting carefully the duration of *spaces* as well as of *lines* and *dots*.

2. What is said of the importance of these directions?

Neglect of some of these precautions has destroyed many valuable instruments and in some cases has caused paralysis of the fingers and fore-arm.

2. *The Alphabet.*—(see frontispiece.) 1. Of what classes of symbols is the Morse alphabet composed?

The Morse alphabet contains two classes of symbols namely: *Visible Marks* and *Measured Intervals.*

2. How are they made?

Symbols of the first class are made by a downward motion and rest of the key lever. The second class requires an upward motion and rest.

3. How are they observed?

The beginning of every symbol is signified to the ear by a click of the sounder, the first class always by a little louder signal than the second. The intervals of rest between downward and upward strokes are to be calculated with equal precision.

4. How many elements in each class?

The first class contains three elements, or visible marks, called the *dot* the *short dash* and the *long dash.*

The second class consists of four different measured inter-

vals, called the *break*, the *spaced-letter-space*, the *letter space* and the *word space*.

5. How are these intervals employed?

1st. The *break* is the ordinary interval between two dots, as in the letters I, S, H, P.

2d. The *spaced-letter-space* is the wider interval used in the spaced letters C, O, R, Y, Z, &.

3d. The *letter-space* is the interval between letters of the same word, as — - - - no.

4th. The *word-space* is the interval between two words, as - — - - - — - - — - - - — - - - - Fine day.

Give the respective values of these seven elementary symbols.

CLASS FIRST.

The dot is the unit for visible marks and measured spaces. The *dot*, *short dash* and *long dash* are valued respectively at *one*, *three* and *six* units.

CLASS SECOND.

The break is much shorter than the dot, a mere interruption of the current in fact, and may be as short as a full and perfect contact on the up stroke will permit.

VALUE.

The *spaced-letter-space* is equal to *two* units. The *letter-space* is equal to *three* units. The *word-space* is equal to *six* units.

7. What is said of the dot?

The dot is not a mere point but must bear, in practice, the definite value of the unit, and be held firmly till the time is up. The longer the circuit, the longer the time required for the dot, and consequently for all the elements of the alphabet.

8. To what fault is the beginner especially liable?

1st. With the key. The beginner is in danger *letting go the key* while at work, either by accident or forgetfulness.

2d. In spacing he is likely to space *irregularly* and generally to make the interval *too short between words*.

3d. In making dots and dashes he will often make the *dash too long* and the *dot too short* and will separate them too far.

4th. In long and short dashes he will *shorten* the *long*

dashes and *lengthen short ones*, thus confounding them, beyond the possibility of their being deciphered.

5th. If letters end in dots he will invariably shorten the last dot.

9. What order is suggested for practice, by Pope?

Pope's Modern Practice gives the following list of exercises: 1st. Master thoroughly the six principles, (frontispiece) of Prof. Smith.

2d. Practice in order E I S H P 6.

3d. " " " T M 5 ¶ L.

4th. " " " A U V 4.

5th. " " " I A, S U in couples.

6th. " " " H V, P 4 in couples.

7th. " " " N D B o.

8th. " " " A F X Parenthesis.

9th. " " " Comma, Semicolon W 1.

Observe that the parenthesis is A U run together, and the semicolon, A F.

10th. Practice in order U Q 2 Period 3.

11th. " " " K J 9 ?.

12th. " " " G 7 !.

13th. " " " O R & C Z Y.

Note. Every teacher will have his preference for particular exercises. These are given as specimens. The ear can be cultivated to detect these letters if attention is given to them continually while practicing with the key. This will hardly create a diversion from the work of "sending" the letters properly, and will soon come to be an important help.

3. *The Telegram.*—1 Of how many parts does a message consist?

The parts of a message are five in number the *Date*, the *Address*, the *Body*, the *Signature* and the *Check*.

These are preceeded by the "office call."

2. What is said of the date?

The *copy* of a telegram furnished the operator, should name the *place* of sending, the *day* the *month* and the *year*. The month and year are seldom transmitted over the line, but must in all cases be supplied by the receiving operator.

3 l. Is the date ever more minute than this?

The hour and minute should be given if requested, otherwise it is optional with the operator.

4. How much is included in the address?

The address contains the full name of the person to whom

the telegram is sent, the city or place, the street and number where he may be found.

5. What is the signature?

The signature is merely the name of the person or firm offering the telegram. It should be preceded by the abreviation *sig*.

6. What is the check?

The check is a record in the interest of the owners of the line giving the *number of words* in the body of the message, the *amount* charged and the *place* of *payment*.

7. The body of the message?

The *body* includes all matter not properly comprehended under any of the above heads.

1. What punctuation is necessary?

A period is used after the address, and after every complete sentence except the last in the body of the message. It is used nowhere else, except in the body. Other punctuation marks should follow copy exactly.

9. What is said of abbreviations in the body of the message?

No abbreviations are allowable in the body of the message. Even *numbers* are spelled out in full. Only in such numbers as one hundred and fifty, the word *and* is omitted, as well as in mixed numbers, such as three and three-fourths, written three three-fourths.

10. What of symbols?

All symbols such as $ & @ etc. are written out thus, dollars, per, at, and so forth.

11. Give a written example of both the copy and of the proper form of a transmitted message.

(The copy.) Columbus O., May. 1, 1875.

Mason, Starr & Everett.

Cor. 14th & Broadway, New York.

Send us six pieces more same quality. Receive draft by mail.

Lyman & Hall.

(The telegram.) Fr Columbus O 1

To Mason Starr & Everett

Corner of Fourteenth & Broadway New York.

Send six pieces more same quality. receive draft by mail

Sig Lyman & Hall

ck 10 pd 60.

12. What are cipher messages?

Words with concealed meanings agreed upon between distant parties are often used to convey secret information. Sometimes they have an allegorical sense and at other times no idea is conveyed except to him who has the key.

13. Give illustrations?

The following are examples:

Cincinnati, Feb. 1st, 1862.

To Gen. Scott, Washington, D. C.

Man Tiger. Hyena sheep. Five paces, count thirty twelve seconds after.

J. C Scout.

Boston, Jan. 17, 1872.

E. J. Fairbanks & Co.

14 Maiden Lane, N. York.

Bad came keen dark loud fault made short seed.

Hardy & Goodman.

4. *Directions for Checking.*—1. What words alone go free of tariff?

The *date*, the *address* and the *signature* only go free. When more than one signature is attached, all of them except the last are counted as part of the body of the message. In such a case each initial is counted a word. A. M. signifying forenoon or P. M. afternoon is counted as one word; C. O. D. (collect on delivery) is three words.

2. Can one send his own address free?

The following rules are adopted by the Western Union Company.

The address of the sender may be transmitted free after the signature. The following are examples of signatures which may be sent free.

JOHN JONES, 31 Bank Street.

JOHN JONES. Answer.

JOHN JONES. Answer at once by telegraph.

JOHN JONES, 31 Bank Street. Answer by teleg'h.

JOHN JONES, 31 Bank Street. Answer immediately.

3. How are numbers reckoned?

Numbers up to twenty are single words. Twenty-one, twenty-two etc. are *two* words. Such an expression as 12x36 should be written out twelve by thirty-six, three, words; 24x48 twenty-four by forty-eight, four words.

Figures, written after numbers for accuracy, are each to be counted a word; thus, forty-eight (48) are *four* words.

4. How are compound words reckoned?

Words which in Webster's dictionary are joined by a hyphen are in the Western Union Company regarded as one word, as rail-road ship-master etc.

Also names of persons or places, as Van Amburg, O'Connor, New York, West Troy are counted single words. But in names of things they are all counted, as "New England Hotel," three words, "Hendric Hudson, (name of steamer,) two words.

5. How are cipher messages counted?

Cipher messages, when composed of simple English words in common use, may be transmitted at ordinary tariff rates; but when such messages are composed wholly or in part of figures, or of arbitrary combinations of letters, or of words of any foreign language, they should be estimated by counting each letter or figure as a word.

6. What are half-rate messages?

Half rate messages are received upon some lines, and are transmitted during the night after all full rate messages have been forwarded. These are to be delivered the next day.

7. How are the charges reckoned?

The charges on such messages are computed at one-half the usual tariff rates, provided the tariff on any message at half rates does not fall short of fifteen cents. Such messages should be written upon blanks furnished especially for them.

8. What is the smallest number of words counted?

Ten words form the basis for checking in this country. Messages containing less than ten words cost the same as ten, but an additional charge is made for each word in excess of that number. Two or more copies of a dispatch, delivered to different parties, are each subject to full rates. When a message passes over two or more lines, the charges must be *all* prepaid or *all* collect. The amount charged should always be stated in cents.

9. What messages are free?

Of course all office dispatches are free. Individuals may have a franchise from the company. The operator should make sure of this before sending messages unpaid.

2—*Classes and Abbreviations.*—What classes of checks are used ?

There are three classes of checks. The *paid* check, the *collect* check and the *free* check. The *collect* check is never to be sent unless a responsible person guarantees the payment.

2. What varieties are there of each class ?

There are two varieties, the *local* and the *through* check. A *local* check is used for a single line, a *through* check for more than one.

3. Give the abbreviations used for local checks.

For a local message containing ten words, for which a tariff of thirty cents has been prepaid, the check reads as follows :

(a) 10 pd 30.

For the same message to be paid at the receiving office, the check reads :

(b) 10 col 30.

On some lines the form (a) is still further abbreviated to 10 30 ; or 10 pd ; or 10. Form (b) appears as 10 col.

4. Is the check ever made to cover more items than these three ?

On some lines the "office call" of the station receiving the money is inserted in the check, thus a message from N. Y. prepaid would be checked 10 N. Y. 30 pd.

If the message originates in N. Y. and is to be paid in Cleveland, the check reads : 10 H 30 col. H being the office call of Cleveland. If the office call is unknown W is used instead.

5. How are through messages checked ?

On through messages the check is changed by each operator who repeats the message. The check will always specify the tariff on the line sending it and the *sum* of the tariffs of all the succeeding lines The last check will then, of course, give only the tariff for that line.

6. Give an example ?

Suppose a prepaid message is to go over three lines, the first of which charges 25 cents for ten words and the succeeding lines 30 and 40 cents respectively, the check will read at the first station 10 pd 25 & 70: at the second 10 pd 30 & 40; at the third 10 pd 40.

7. How is the *collect* through message checked?

For the through message not prepaid the system of checking is directly the reverse. The first station mentioning only its own tariff and every other one specifying its own and the sum of all those that preceeded it.

8. Give an example of collect through checks?

Suppose the message starts from office A whose charges are 25 cts, and goes through B which charges 30, and C which charges 35 cts. The checks will read as follows:

(At A,) 10 col 25.
(A tB,) 10 col 30 & 25.
(At C,) 10 col 35 & 55.

9. How are the charges paid in this case?

The first line receives its pay from the second, the second gets from the third *its own* and *the preceeding* charge, the last collects from the customer the whole amount.

10. What is signified by the abbreviation "pa" in a check?

"Pa" is an order to the receiving operator to pay the sum following it to the person or company mentioned, usually to a message boy.

11. How are free messages checked?

The letters D H (dead head) are used to check a free message, the words, however, implying no censure, whatever.

3. *Examples for Practice.*

In the following examples 5 cts. is to be allowed for odd words until their sum amounts to the tariff for ten.

1. Write on the black-board (or paper) the check for a message of fifteen words over a single line on which the tariff is thirty cents for ten words.

2. Write the local check for a message of nine words where the charges are 25 cents for ten words.

3. Write the check on the following through message over three lines each of which charges 25 cents for ten words." "Come home directly, Father is sick.

4. Write the check on the through message over four lines the first two of which charge 25 cts each for ten words, the second and third charging 30 cts each for the same. "Good news from Willie and Mary. When do you sail? Don't forget my friend Jennings at 17 Rue, Saint Honore, Paris."

5. Write the several checks for the through message over three lines which charge respectively 20 cts., 25 cts and 30 cts for ten words. "Erie looking up, buy 500. Sell 1000 Pacific Mail."

6. Write the check for a free message of twelve words over each of three lines which charge severally 25 cts. for ten words.

7. Check the following local message the tariff being 35 cts for ten words: "Send 25 gross at thirty days. Demand increasing, sold five yesterday."

8. Check the through message for each of three lines whose tariff is 30 cts. for ten words. "Great Western arrived. Mails bring news from Frankfort on the Rhine to 25th.

9. Write in full for transmission the following message. Tariff 50 cts.

Oberlin, Jan. 25 1869.

J. B. Gough, Chicago, Ill.

Dear Sir, will you lecture here on the 27th inst. Answer.

James F. Baldwin, No. 3, College St.

10. Write in full the following message, through Wellington to New London, O. Tariff 25 & 30 cts.

Oberlin, O. Dec. 2, 1870.

A. B. Chase & Co.

Send 10 yds. best broadcloth by U. S. express, C. O. D.

John Armor, Park House.

11. Write in full for transmission the following telegram. Tariff 45 cts.

Cleveland, O. July 3d. 1874.

Frank B. Starr,

227 W. 23d, Street, N. Y.

Your stock sold. Lake Superior Pig advanced 1½ per cent.

Harvey Rice, 31, Johnson Street.

4. *The Office Call.*—1. What is meant by the "call"?

Each office has a "call" which may be an abbreviation of its name, as N. Y., or some one or more letters or figures agreed upon. The "call" of an office is also its signal or signature. Every operator must be able to recognize his call *by sound* even though he do not read messages by ear.

2. On what occasions is the operator to use his own office signal?

The operator should sign his office call to every thing he transmits, whether it be a call, an answer to a call, a message or simply conversation.

3. What is the mode of calling?

The operator who wishes to communicate with another office, makes the call of that office three or four times, and then signs his own office signal; repeating this operation till he receives a reply or tires of calling.

5.—Cautions to be Observed by Operators.—1. What caution is given to insure perfect copy of a message?

The copy should be in the customer's own hand writing. If the customer cannot write, the operator should not send it from oral communication, but write it himself and read it to the customer, securing his assent and, if possible, his signature. Accuracy is all important, a slight error may involve great vexation and loss.

2. What caution concerning the address?

The address both of sender and receiver should be carefully kept by the operator for self-defense in case of any error of the carrier, and to facilitate the delivery of the message and its answer. It should be attached to the copy and put on file.

3. How should unreasonable demands be met?

An operator should be courteous to all sorts of people. Politeness and forbearance must *never* be laid aside however unreasonable the customer may be, but unjust or foolish requests, the operator has no right to grant.

4. What should be done with copies of telegrams?

All communications by telegraph are strictly confidential. Every copy should be preserved, subject only to the inspection of the responsible officers of the company. *Messages received* are to be filed away out of sight, the date of reception, and hour and minute of transmission being carefully marked upon each.

5. What caution is given concerning the forwarding of a message?

The operate must never *commence sendiug* a dispatch till he is *sure of a hearing*, that is till he hears the response, "I, I", followed by the office signal of the receiving office.

6. What if the sender detects himself transmitting a wrong word or figure?

If the operator stumbles, he is to say msk. (mistake) and go back to the last correct word. If he forms a *letter* incorrectly he should repeat the whole word in which it occurs.

7. What caution is given for writing to an operator who receives by paper?

Give an operator time to adjust his register. The sender should make a few dots before sending the message.

8. What extra care is given to *insured* messages?

An insured message is repeated back to the sender, who carefully compares it with copy, and makes a memorandum on the margin of the latter certifying the correctness of the return and other circumstances attending the transmission.

9. What *call* is made for through messages?

For a through message over several lines the operator calls the station next succeeding his own and writes "thru" on his message. The second calls the third and so on.

10. When does the sending operator's responsibility for the message cease?

The sending operator is responsible for the message until he receives the reply O. K. (oll korrect) "signed" by the receiving operator.

11. What are the responsibilities of the receiving operator?

The receiving operator is to compare the *number of words* in the body of the message with the *check*, and make sure that they agree, or else inform the sender and have all mistakes corrected before he replies O. K. The message may be repeated by *initials* (*i. e.* giving the first letter of each word,) or in some cases the whole may be repeated for this purpose.

12. What if the receiver fails to get a word?

If the receiver is in doubt about a word he should interrupt the message by the signal G. A. and give after it the last word he understood.

13. What is the first receiver of a *thru* message to do?

He is either to copy the message and send it forward or put the first and second stations in direct communication by a repeater. The second receiver does the same for stations two and three.

14. How long may the receiver of a message keep his key open?

No operator should keep the circuit open a moment longer than is needed to insure the perfect reception of a message. Other stations are waiting for it.

CHAPTER IV.

RAILROAD TELEGRAPHY

The following chapter on railroad telegraphy* is designed to give students a general idea of the most approved methods of moving trains by telegraph. While the systems of several different railroad companies have been carefully considered, and points from all here embodied, especial use has been made of the materials kindly furnished by officials of the Pittsburgh, Fort Wayne and Chicago Railway, and the Pittsburgh, Cincinnati and St. Louis Railway.

1. Train Reports.—1. What are train reports?

Operators are required to keep a record of all trains which pass their stations, as well as reports of trains from other offices.

2. How and Why are they kept?

This record must be kept in a book provided for the purpose, must be written in ink, and every care must be taken to ensure perfect accuracy. It is often required that the train register, or a duplicate thereof, be forwarded to the Division Superintendent or Train Dispatcher, at stated times, for inspection.

3. How can operators obtain the record?

Operators wishing a repetition of any train report, should apply to the Division Superintendent's office.

4. What is the form of train reports?

The *form* of train reports varies on different lines. The common form is as follows: Make "O S" six times and sign your office call; then give the number of the train together with the direction in which it is going, saying "on time;" or, if late, stating the exact time of its arrival or departure in figures.

5. What more is sometimes required?

On some lines the operator is required to call the Division

*From Mattison's Manual.

Superintendent's or Train Dispatcher's office five times, then sign his office call, and then proceed with the "O S" (omitting office call *after* the "O S" and report as before.

6. How is the time designated?

Sometimes both letters and figures are employed to designate the time.

7. What abbreviations are used?

The abbreviations are "A" or "Ar," for arrived, and "D," or "Dep." for departed. The following are examples of train reports:

8. Give examples of train reports from station U, when the train dispatcher's office is Q.

(*a*) O S (*six times*) U. No 6 east on time U.
(*b*) O S " U. No 6 east ar 345 U.
(*c*) O S " U. No. 6 east ar 340 U.
(*d*) O S " U. No 6 east ar 340 dep 345 U.
(*e*) Q (*five times*) U O S (*six times.*) No 6 east ar two-fifteen 215 U.

9. What is the operator's duty when a train is behind time?

When trains are delayed behind their schedule time, the operator should endeavor to ascertain the cause and report it to the Division Superintendent's office.

10. How are extra trains reported?

Whenever a regular train is followed by an *extra*, the operator should designate the extra as "Extra, No ——," according to the number of the regular train which precedes it.

1. Train Orders.—1. How are *train orders* given?

All special orders by telegraph for the movement of trains should be given in writing. Whether addressed to the conductor alone, or to the conductor and engineer (as is customary on some lines,) the mode of procedure is essentially the same.

2. What is the mode of procedure?

The conductor should sign his name to the original order, as written by the operator, who must then repeat it back to the office from which the order was received, prefixing "13" (I understand) and annexing the conductor's signature. The person who sent the order will then respond "O K," followed by the exact time, which the operator should endorse upon

the order. The operator should make *two* copies of the order, both of which must be given to the conductor, who should satisfy himself that they are exact copies of the order previously signed by him, and hand one to the engineer. Both copies should be signed by the operator.

3. How much is included in a train order?

An order naming any train *includes all sections of such train*, unless otherwise specified in the order. It is necessary, however, that the conductor and engineer of *each section* should have copies of the order.

4. What method is used for making several copies at once?

In order to obviate delay and ensure accurcy, the use of *manifold paper* was introduced by the P. F. W. & C. railway company, about a year ago, and the custom has become quite common on the more extensive railways.

5. How can repetition of orders be saved?

Operators having the same order for a number of different trains or sections, need not repeat the order for every train or section, but after sending the reply once and getting the O. K. to it, can then add the balance of the signatures, giving the number of the order before each signature, and getting the proper O. K. for each.

6. What caution is given in sending figures?

When figures occur in special orders sent by telegraph, they should be duplicated with a comma between.

Operators should be positive that all copies made for delivery correspond with the original copy received.

7. How are special orders numbered?

Special orders should be numbered consecutively, commencing with No. 1 each week. When practicable, orders will be sent to the different trains named in the order at the same time.

8. How is the operator personally connected with a special order?

In sending special orders and answering O K to the same, operators will invariably *prefix their own initial* letters to their office calls.

9. When several are to answer which has precedence?

When an order is sent to more than one office at the same time, the station first mentioned in the order will take precedence in answering O K.

10. How is the receipt acknowledged?

On receipt of an O K to an order, the operator should say, "I I" and sign his personal letter, signifying that he has received the same.

11. When shall the reply to a special order be made?

Operators must not, *under any circumstances*, send the reply to any special order, until such order has been properly signed by the parties to whom addressed. They must use great caution in receiving orders for trains, and must not give an O K to an order unless they are positive that the train has not passed, and that they can put out the proper signal in time to stop the expected train.

12. How are such orders kept?

Operators will copy all special orders in a book provided for that purpose, and will also record on the margin of such orders the initial letter of the operators receiving or sending them, together with the correct time received or sent.

13. How can the operator get possession of the circuit for his order?

The signal "2" should be used by operators when they wish to obtain the circuit for train orders, but they must not use this signal when a train order or a message is occupying the line. This signal and the number of the order will be given at the commencement of every special order or reply thereto.

14. How does the Train Dispatcher secure the line?

The signal "9" will be employed by the Train Dispatcher or general officers of the company, and will take precedence over all other business. If the Train Dispatcher wishes this signal used to get a reply to an order, or to report a train for orders, he will so instruct.

15. Who alone has a right to the signal "9" and O K?

Operators in the Train Dispatcher's Office are not permitted to give the signal 9 or O K to train orders, until so directed by the *Dispatcher*.

16. How does the answer begin?

In answering an order the operator should in all cases begin by repeating the number of the order.

17. Whom are conductors of trains to address for orders?

Communications from Conductors concerning train orders should be addressed to the Division Superintendent.

18. What is the operator's duty with regard to holding a train?

Whenever an order is sent to a station agent, operator, or other station employee, to hold a train for any purpose, the order must be as strictly observed as if addressed to the conductor or conductor and engineer. In such cases copies of the order should be delivered to the conductor and engineer; and this must be done even when the train for which they were held has arrived.

19. Is the Train Dispatcher the highest authority?

The Train Dispatcher represents the Superintendent, and his rules are to be respected accordingly.

20. What is the great rule of safety which guides the Train Dispatcher?

The rule of the profession is: Never move trains by special order until a positive response has been received from reliable parties, which will insure the stoppage of the trains possessing the right to the road. If it be possible, the response should be from the conductor himself of the train named in the order. In every case *absolute safety* should be insured, even at the expense of delay.

2. Forms of Train Orders.

The following forms of train orders are in daily use upon the Pittsburgh, Fort Wayne and Chicago railway, and to the kindness of one of its officials we are indebted for a complete specimen. Although the general forms here presented are usually adhered to, the wording is slightly varied according to circumstances.

A REGARDLESS ORDER.

ORDER, No. 345. Di. 16.

Conductor No. 4, J.
Conductor No. 1, Kn.

Train No. 1 will run to Massillon, regardless No. 4. Answer. R. W.

A TIME ORDER.

ORDER, No. 346. Di. 16.

Conductor No. 4, Fs.
Conductors No. 15, Ud.

Train No. 15 has until 3:45 P. M. to go to Lucas against No. 4.

Answer. R. W.

TIME ORDER—ANOTHER FORM.

ORDER, No. 347.

Conductors No. 2 & 12, J.

Train No. 12 can use 1 hour on time of No. 2 to run from Wooster to Orville.

Answer. R. W.

A MEET AND PASS ORDER.

ORDER, No. 348. Di. 16.

Conductor No. 13, D.

Conductor No. 16, Sv.

Trains No. 13 & 16 will meet and pass at Wooster; No. 13 take siding.

Answer. R. W.

ORDER, No. 353.

Conductor No. 9, D.

Conductor No. 10, Ca.

Trains No. 9 & 10 will meet and pass at Salem; No. 9 take siding.

Answer. R. W.

A RED FLAG ORDER.

ORDER, No. 349. Di 16.

Conductor No. 6,

Conductor Extra East,

Train No. 6 will carry red flag Crestline to Alliance for extra passenger train.

Answer. R. W.

A WHITE FLAG ORDER.

ORDER, No. 350. Di. 16.

Conductor 12,
Conductors extras } In

Train No. 12 will carry white flag Crestline to Alliance, for extra freight trains.

Answer. R. W.

A DISCONTINUING ORDER.

ORDER, No. 351. Di. 16.

Conductors 4th & 5th No. 16, Rs.

Fourth section, No. 16, will take in red flag at Lucas; 5th, No. 16, is discontinued at Lucas.

Answer. R. W.

ANOTHER DISCONTINUING ORDER.

ORDER, No. 352. Di. 16

All Conductors of Trains & Agents interested.

Train No. 10, this date, Alliance to Pittsburgh, is discontinued. Notify all parties interested.

Answer. R. W.

CHAPTER V.

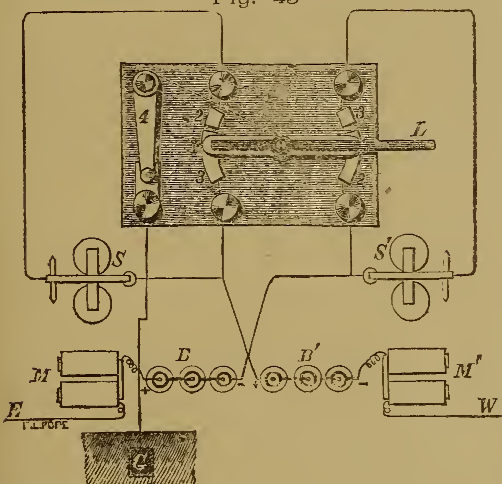
PRACTICE WITH CIRCUIT CHANGER.

1. ***Repeaters.***—1. How is the circuit directed after passing the *repeating* relay. (*p.* 52 Q. 20)

The proper direction may be given by the Culgan, or other switch; but instruments are preferred which are constructed expressly for the purpose and are simpler in their operation.

2, What is Wood's button repeater?

Fig. 45



Wood's Button Repeater.

Wood's repeater is a compound switch of very simple form, extensively used for this purpose. The shaded rectangle in Fig. 45 exhibits the instrument with its button (4) and lever L. The dotted lines show the course of the wires underneath the switch board. The necessary batteries and instruments, except the usual local connections, are given in outline to assist the learner in understanding the arrangement. **E** and **W** are the east and west Main lines, **M** and **M** are the relays, **S** and **S** the sounders and **B** and **B** the batteries belonging to them respectively. The batteries are placed with *opposite* poles to the ground, as if they were at the terminals of the line

3. What arrangement will give two independent circuits?

For *two circuits* close the button 4 and let the lever L stand on number 1, as in the figure.

4. How is a through circuit produced?

For a *through* circuit *open* the button 4 which throws off the ground connection between the batteries; leave the lever **L** on number 1.

5. How can the Eastern sounder be made to repeat into the Western circuit?

Close button 4 and turn the lever **L** so as to connect 2 & 2.

6. How can the Western sounder be made to repeat into the Eastern circuit?

Close the button and turn the lever to connect 3 and 3. These two processes give two distinct circuits arranged for repeating.

7. What is Pope's simple rule for the guidance of the operator?

Rule. When either sounder fails to work coincident with the other, *turn the button instantly.*.

8. What simpler arrangement will sometimes answer?

If we never wish to work the two lines *through* in a single circuit the main battery is placed in the circuit between the middle of the lever and the ground, and the button is always kept closed, or is dispensed with entirely.

9. What is the principal objection to this repeater?

Wood's repeater requires the constant attendance of an operator to change the lever between a message and its answer, as is evident from questions 5 and 6 above.

10. How is this difficulty met?

In Hick's repeater the change is accomplished by a delicate arrangement of magnets so that the operator at the eastern extremity of the circuit leaves the line in the possession of the operator at the western extremity and vice versa.

11. What attention does Hick's repeater demand?

The relay needs adjustment and attention and the extra local batteries which assist to operate the automatic part, have to be kept at a uniform strength.

12. How does Milliken's repeater differ from Hick's?

In Milliken's repeater the automatic arrangement is preserved, but the extra local battery is independent, and a slightly varying strength causes no disturbance.

13. What is Bunnell's improvement?

Bunnell's Automatic Repeater dispenses with the extra

local batteries in adjusting the relay armature, and makes use of the principle that a current which traverses two coils of unequal resistance, one of which, for example is of large wire and the other of small, will cause *more magnetic power* in the core of the helix which *has the greater resistance.* The helix of the controlling magnet is therefore of finer wire than that of the repeating sounder.

14. What other advantage has the repeater?

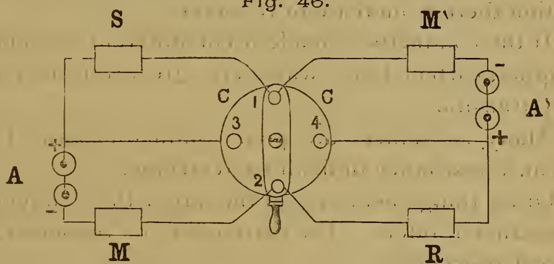
In Bunnell's repeater no other adjustments are required than those of the simple relay and sounder. Both sides also operate at the same time, so that the operator can always judge how both lines are working.

2. Local Circuit Changer.—1. What is the object of the local circuit changer?

It is often important to change a set of instruments to a different line. For example: Suppose a sounder is placed on one circuit, and a register on another in the same office. The operator may wish to use the register on either line. This is accomplished by means of the circuit changer.

2. What is the operation of the instrument?

Fig. 46.



In Fig. 46 **M** and **M'** are the relays **S** the sounder and **R** the register; **A** and **A'** are the local batteries; **B** is a small button switch, having four connecting points, numbered 1, 2, 3, 4.

When the button connects 1 and 2 the relay **M** works the sounder **S**, and **M'** the register. When it connects 3 and 4 **M** works the register and **M'** the sounder.

CHAPTER VI.

RESISTANCE OF THE CIRCUIT.

1. What is meant by the resistance of the circuit?

All electrical currents encounter a degree of difficulty in passing over what are called conductors. This difficulty is called the *resistance* of the conducting medium, or of the circuit.

2. On what does the amount of resistance depend?

Many things combine to determine the degree of resistance.

(a.) On a wire of uniform purity and size throughout, the resistance depends upon the length.

(b.) If the wire changes often in size, at every place of diminution there is increase of resistance.

(c.) If the conductor is made up of different substances as zinc, copper, carbon, brass, water, etc., great resistance results at every transition.

(d.) Many substances are poor conductors and of themselves cause resistance difficult to overcome.

(e.) Other things being equal the larger the conductor the less resistance it offers. The earth offers no resistance, a fine wire great resistance.

(f.) The battery itself offers great resistance as the current has to pass through many different media. The smaller the cells, too, the greater the resistance.

(g.) If the plates are far apart the resistance is greater; also if the cells are far apart the battery resistance is unnessarily great.

(h.) In a *quantity* battery the resistance is diminished by the number of cells; thus ten cells joined as one give only one tenth the resistance of one; while ten arranged for intensity give ten times the resistance of one.

(i.) A dry cell or one partially dry, or otherwise defective, will cause great resistance.

(j.) Pure water offers great resistance while saline waters offer much less. Rain in the city atmosphere causes much greater leakage of current than the pure rain of the country.

3. How is resistance manifested?

Resistance to the circuit is like friction to ordinary motion, it manifests itself by *heat* or by *magnetism*, in short by taking some other than its original *form* of force.

4. How may it often be detected?

Any unusual heat about the connections of an instrument, or about a battery, points unmistakably to unusual *resistance* which in most cases results from looseness of the binding screws.

5. If we wish to *produce heat* by the current how is it effected?

To produce heat it is only necessary to use a poor conductor, like carbon cut thin, or to pass the current over very fine wire. A fine platinum wire is heated to a white heat or melted by the current of one cell.

6. Why is the relay magnet made of fine wire?

When the current enters the relay it is already feeble from the resistance of the line, but by traversing the helix of very fine and very long wire. The effect is multiplied by the number of turns of the wire without much increasing their distance from the core.

7. What is the *effective* force of a current?

The effective force at a station is what is left of the current after the loss resulting from all resistance and waste is subtracted.

2. *Measurement of Electric Force.*—1. How can the resistance of different circuits be compared?

The unit of resistance is called an *ohm* and is equal to that offered by 1-16 of a mile of No. 9 galvanized iron wire. A megohm is one million ohms. A microhm is one millionth of an ohm.

2. Illustrate the use of the term?

Suppose it is said that a certain relay offers 64 *ohms* resistance. The meaning is that its resistance is equal to that of 4 miles (64÷16) No. 9 galvanized iron wire.

3. What is the rheostat?

The rheostat is a collection of coils of wire made of an alloy of metal having a high resistance. Each coil has a certain number of ohms resistance, a few having a large number and others a smaller number in some cases down to a single ohm. It is analagous to a measuring pole having large and small divisions marked upon it.

4. How is it used?

The current may be made to traverse any number of the coils until its force is spent and the number of ohms of force to which it was equal thus known.

5. Illustrate by an example?

A current may traverse one coil marked 10,000, two coils marked 1000, one coil marked 100 and three more marked 10 each. If now, tested by a galvanometer it must still show some force but not enough to traverse another 10 ohm coil. Coils of a single ohm are then added to the circuit till it ceases to affect the needle. The sum of all the ohms on the coils traversed will be the measure.

6. Do not resistance coils change their indications in time?

Resistance coils, will endure for many years without appreciable change, except the very slight one from temperature, which is known and corrected in nice calculations.

7. What other use have they than to measure force?

They are used whenever it is necessary to reduce a force to the electrical *potential* of another force, *i e* to make the two equal. Resistance coils are then introduced into the stronger circuit.

8. What is the unit of force?

The unit of force or tension is called a *volt*, it is very nearly equal to the force of one Daniell's cell. More exactly Daniell's cell=1,079 volt. The mega-volt=one million volts. The micro-volt, one millionth of a volt.

9. What is the unit of quantity?

The unity of quantity is one farad. It is the quantity of electricity which, with a force of one volt, will flow through a resistance of one megohm in a second.

The mega-farad=one million farads.

The micro-farad=one millionth of a farad.

10. What is the unit of current?

The unit of current, derived from these units, is the current of one farad per second. In other words it is the current which would flow through one megohm of resistance with a force of one volt, or through one ohm with a force of one micro-volt.

CHAPTER VII.

INTERRUPTION OF THE CIRCUIT.

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1. What are the principal forms of interruption of circuit?

The most common interruptions are termed *breaks and partial disconnections*, *escapes and crosses*, *reversed batteries and electrical disturbances*.

2. What is a break?

Any rupture of the line is termed a break.

3. What three cases arise from a break?

In the first case *neither* of the broken ends communicates with the earth, resulting in a total arrest of the current.

In the second case *one* end communicates with the earth. At that end of the line a shorter circuit is formed, at the other there is no circuit.

In the third case *both* ends communicate with the earth and a distinct circuit is formed at each end.

4. What is a partial disconnection?

A partial disconnection is formed by loose or rusty joints in the wire or loose screws in the instruments.

2. *Escapes and Crosses* —1. What is an escape?

When a partial connection is formed between the line and the earth as by moisture or dirt in the instruments, rain on the posts, contact with trees or other conductors, the loss of electrical force thus produced is termed an escape.

2. What is a *ground?*

A total escape is called a *ground.* It is like the third case of a break. A complete circuit is formed at each end of the line.

3. How is an escape temporarily remedied?

It is common to make up for an escape by adding to the battery. The ~~only~~ thing, however, which will avail is to *increase the quantity but not the intensity*, [p. 33.] Increasing the intensity aggravates the evil, while increasing the quantity supplies the waste.

4. What is a cross?

When two wires make a contact a cross is formed—either wire can be worked if the circuit of the other is opened. *Swinging contact* is a temporary or intermittent cross.

5. What are weather crosses.

Weather crosses are produced by a leakage of the current from one wire to another on the same poles, through defective insulation. Parallel wires too near together sometimes excite induced currents, which, by some writers, are confounded with weather crosses.

6. How will defective ground connection affect the circuit?

If the ground plate does not reach moist earth the effect is much like a cross. A soldered connection with a gas or water pipe is always best.

3. Reversed Batteries.—1. What are reversed batteries?

When two batteries in the same circuit are placed with like poles toward each other they are said to be reversed.

If the two batteries are equal no currents will pass since they oppose each other with equal force.

2. How would it be at a station between the batteries?

An operator at a station between the batteries could get a current from either, by putting on his ground wire, as this divides the line into two circuits.

4. Electrical Disturbances.—1. What are the principal electrical disturbances?

Electrical disturbances include electric storms, earth currents, and earth-battery currents.

2. What is an electric storm?

The atmosphere and clouds are nearly always more or less charged with electricity which acts inductively upon the telegraph wires.

When this becomes excessive as just before or during a thunder storm, or during the prevalence of the Aurora Borealis it is termed an electric storm.

3. How does an electric storm affect the wires?

During these storms the wires become heavily charged and but for lightning arresters the instruments would be destroyed by the burning of the insulation or fusing of metals, and the lives of operators would be endangered.

4. Are these storms ever experienced in clear weather?

A station may be at one end of a long line where the weather is fine while the storm is present at the other, the disturbance will exist throughout the line.

5. What precaution should be observed?

On the approach of an electric storm the relays and sounders should be removed from the circuit to guard against injury.

6. What are *earth-currents*.

Currents are constantly traversing the wires which are neither derived from the battery nor from the atmosphere, these are called earth currents.

7. Do earth currents follow any law?

The strength of these currents is evidently affected by the direction of the terminal stations from each other, *i. e.* they are usually stronger over north and south lines than over those running east and west.

They are affected by the heat of the sun and often change with the hour of the day though not with regularity.

8. What other cause may produce earth currents?

They are closely related to electric storms. Although the tension of the earth is put at zero, yet the presence of a highly charged cloud over any locality will act inductively to raise or lower the *potential* or tension of the earth directly beneath it and determine earth currents in that direction or the opposite. The discharge of such a cloud into another more distant would reverse the currents on that side of the locality.

9. When are they strongest?

They are strongest during magnetic storms, so-called in which the compass needle is usually agitated. Sometimes they have been as powerful as the current from eighty Grove cells and have yielded sparks.

10. What are *earth-battery* currents?

Earth battery currents are those which arise from using different metals for the ground plates at opposite ends of the line. As the earth offers no *resistance* a battery is formed by these plates precisely as if they were near together. The remedy is to make the metals alike.

CHAPTER VIII.

LOCATION OF FAULTS.

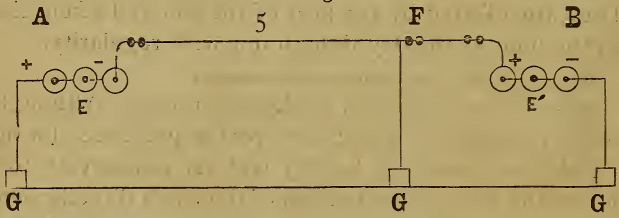
1. ***Testing for a Break. Preliminary matters.***—Do all stations use a ground wire?

Ground wires are furnished to all stations, but only those supplied with main batteries use them constantly. For convenience these are called terminal stations.

2. What use would an intermediate station have for a ground wire?

Suppose **A** and **B** are terminal stations and **F** is intermediate. **E** and **E′** are main batteries, and **G** and **G** ground plates.

Fig. 47



If **F** puts on his ground wire the current from either main battery will go to the ground at **F** and return. It is evident that **A** and **B** can not in such a case communicate with each other though either can communicate with **F**.

3. Must F put on his ground wire in order to communicate with A?

If the main battery is large enough **F** can get a message by placing his relay in the main circuit without using the ground wire.

2. ***Testing for a Break.***—1. What special use has the ground wire at intermediate stations?

The ground wires between terminal stations are especially useful in locating a fault.

2. Describe the process?

Suppose a break to occur between **F** and **B**, as at 5, both of the broken ends communicating with the earth. In this case the intermediate ground wire will not be used. If **A** wishes to communicate with **B** he can get no response. The current enters the ground at **F** and returns to **A**. **A** will call successively on every office between **B** and **A** until he receives a reply. He infers correctly that the break is next beyond the station which first answers. **B** will locate it in the same manner. Either **A** or **B** can work with all offices between themselves and the fault.

3. What is the second case?

But if neither end of the broken wire makes contact with the earth, it is evident the main circuit entirely stops. No relay on the main line will work. Suppose **F** to make this discovery. He tries his ground wire for each end of the line and finds he can communicate with **A** when the current is directed from **A** through his instrument to the ground but not so with **B**. This enables him to locate the fault between himself and **B**. The process is the same at each intermediate station until the fault is located.

4. What is the third case?

If one broken end makes contact with the ground while the other does not, one of these methods is employed on one side of the break snd the other on the other side.

3. *Testing for an Escape.*—1. How is an escape located?

The operator at **A** (Fig. 47) calls each station in rotation beginning with the most distant, and asks to have the key open for a short time. Until he passes the escape, opening the key will not entirely arrest the circuit as it ought to do if the line were perfect, but when the key is open *between* **A** and the fault the current is entirely cut off.

2. Illustrate this?

If for example the escape were at 5 in the figure, an open key between 5 and **B** would not prevent a current passing from **A** to 5 where it would descend to the ground by the

escape and so return to **A**. But when the key at **F** is open the current can not reach the escape and so can not make the circuit.

3. How is a total escape located?

A total escape is located in the same manner as a break.

4. *Tisting for Crosses.*—1. How is the existence of a cross ascertained?

If a message sent over one line returns to the same office instantaneously on another line there is probably a cross between the lines.

2. What is a possible cause?

There *might* be a leakage from one wire to the other caused by a kite-string or other conducting substance caught on the wires, or by moisture, or from any of the causes mentioned in the previous chapter.

3. How is the cross located?

Let the key be opened at each end of one of the lines, this relieves the other line from the effect of the cross.

Now let messages be sent by each operator in turn on the relieved line, commencing at **B** and running back to **A**. The message will come to **A** on *both* lines until it starts from a station between **A** and the fault.

CHAPTER IX.

TESTING BY MEASURE.

1. *Comparative Advantage of this Method.*—1. What objections are there to the tests described in the preceeding chapter?

These tests already given are useful only for locating faults approximately. In the grosser and more obvious faults they may be all that is necessary, but for keeping a line in thorough working order throughout they are wholly inadequate.

2. *The Instruments.*—1. What are the instruments employed for this purpose?

The instruments for the measurement of resistance have been already described, they are the rheostat and the galvanometer.

2. What variety of the galvanometer is best?

Perhaps the *differential* galvanometer is more used than any other. It differs from the ordinary instrument by having two separate coils, a right hand and a left hand helix, of exactly the same resistance and so placed as to exert an equal effect on the needle. The instruments will have two positive and two negative terminals.

3. How is the differential galvanometer applied?

If a battery current is applied to two of the terminals, generally the two central ones, as the resistances are equal, one-half of the current will pass through the right-handed helix and the other half through the left handed one. The needle will therefore remain quiet. Now if equal resistances be added to each coil the needle still remains motionless, but if unequal resistances be added the **N** pole of the needle will be deflected toward the side which has the least resistance, as this allows more electricity to pass than the other.

4. Will a galvanometer bear the whole power of a main battery?

The current of a large battery would be likely to destroy a galvanometer helix even if divided as in the differential apparatus.

5. How is this avoided? (See Appendix A.)

The instrument is provided with a shunt or loop which has a resistance exactly equal to 1-99 of that of one of the coils of the galvanometer. Accordingly when the battery current is turned on, 99-100 of it passes through the shunt and only 1-100 through the galvanometer.

9. How is the differential galvanometer changed to one of the ordinary kind?

The current can be directed through either of the coils *singly*, the other being "cut out," when it will be in suitable condition for ordinary testing to find broken connections, loss of insulation &c.

3. *Practice with the Galvanometer.*—How often should the line be examined with the galvanometer?

The resistance of every main line circuit should be measured every morning, and much oftener if there are marked changes of weather, and the mean of all the resistances should be recorded.

2. How is the line prepared for testing?

Every key is closed and the ground wires are taken off, leaving the line perfectly insulated throughout. This gives it the same tension in every part.

3. How is any current at all to pass such a line?

If there were no escapes in any part of course no current would pass, and this is precisely what is to be ascertained.

4. How much resistance ought such a line to show?

If again the insulation were perfect such a line would offer *infinite* resistance; although the current would *flow into it*, and give it a potential equal to that at the battery. The needle would stand at o.

5. In practice how much resistance is to be expected, allowing for *unavoidable* escapes?

Even in wet weather a line in good order, of two hundred miles length, ought to show a resistance of 5000 ohms. If we try half the same line, of course we have now only *half the escapes*, and the resistance is, therefore *doubled*. For a single mile the resistance should be 200 times 5000 ohms, or a megohm.

6. Suppose there is considerably less resistance than this?

If the resistance is much less it proves that there is unnecessary, or at least unusual escape, somewhere, and we proceed at once to locate it.

7. What is the counter-test?

The counter-test is made by putting on the ground at one terminal while the galvanometer is applied at the other. The ground wire if perfect gives a total escape, and the other escapes are nothing in comparison.

8. Why will the current then flow?

The current always flows toward a point of lower potential. The potential at the battery may be be taken at 100, the potential at the other terminal is 0. And at any point on the line it is in exact proportion to its distance from the battery.

9. How then can we now ascertain whether the line has the proper resistance?

The resistance in this case increases with the length. If each mile of No. 9 galvanized wire give a resistance of 16 ohms when perfectly insulated except at the terminal, then 200 miles should give 3200 ohms.

10. Suppose the resistance too low, how now is the fault located?

First we suppose that by frequent measurements the proper resistance per mile is known. Now if the broken line makes full contact with the earth the resistance of the broken line *divided* by the resistance per mile gives the distance of the fault from the operator. If the test at the other extremity gives a corresponding result the location is perfect.

11. How do we know whether the break does make full contact or not?

If the contact at the fault is imperfect as is generally the case the resistance of the broken line is now *greater* than that of the whole line with a ground wire at the terminals and the same experience is found at each terminal station.

12. Illustrate by a case of perfect contact?

Suppose the line to be 100 miles long and that its average resistance is 1400 ohms or 14 ohms to the mile. If now the test at **A** one extremity of the line shows 854 ohms resistance this indicates 61 miles. If the test at **B** gives 546 ohms it indicates 39 miles and the fault is located.

13. Illustrate a case of imperfect contact?

Suppose the test at **A**, one end of a one hundred mile line, to indicate 76 miles and the test at **B** to indicate 32 miles. This is 12 miles in excess of a hundred. The first indicates the fault 76 miles, say west, from **A**, the other points to 32 miles east of **B**. The true place is midway between the two localities indicated.

14. Will this method apply to any other fault than a break?

This applies to any fault arising from increased resistance. A careless operator has had a defective connection traced into his very office by a skillful tester fifty miles away.

4. The Loop Test.—1. What is the loop?

The loop is made by connecting the faulty wire with a perfect one running from the same office. The connection is made at a station beyond the fault and as near to it as may be ascertained without measuring.

2. Why is the loop test preferred?

This test is more accurate, and can be used whatever be the resistance of the fault itself. It is therefore available for a varying resistance.

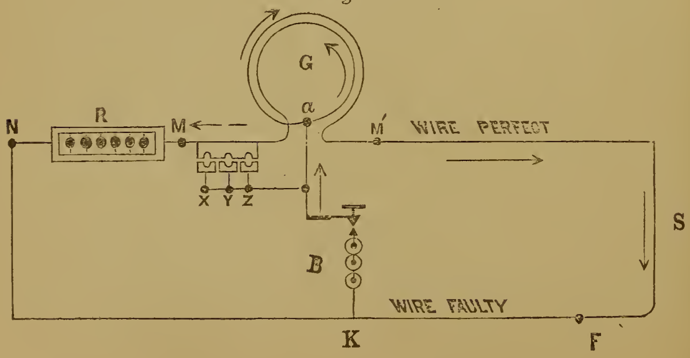
3. Describe the test for an escape in general terms?

The method is first to measure the resistance of the loop, and if we know from the record what the resistance of the two wires constituting the loop should be, when there is no fault, then half the difference between the recorded and the present resistance is the distance in ohms of the fault from the distant station.

4. Give the steps for finding the resistance of the loop?

B Fig. 47 represents a carbon battery. The current ascends in the direction of the arrow to *a* the common terminal of the two coils of the differential galvanometer **G**. Here the current divides and after traversing the two wires of the galvanometer one branch of it flows to the right through the loop, which

Fig. 48.



begins at **M'** and passing around by the distant station **S** returns to the battery. The other branch flows to the left through the rheostat **R** and back to the battery. The portion from **M** through **R** and **N** to the battery is all in the office.

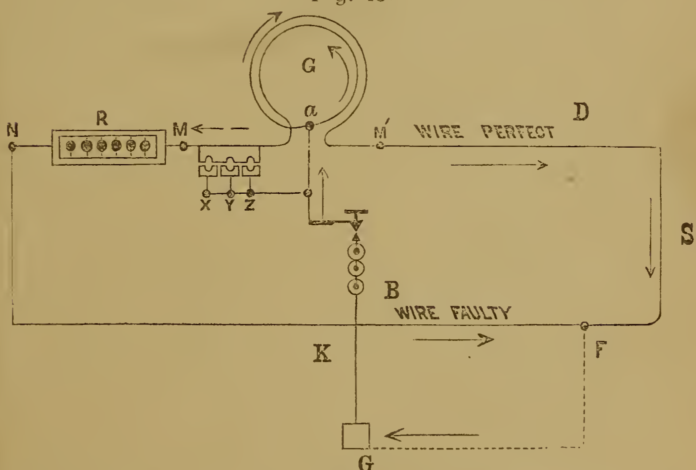
Resistance is added in the rheostat until the needle stands at zero. This gives the resistance of the loop. If the current is too heavy for the galvanometer a portion of it may be passed through the shunts *x y z*. The currents returning to the battery reunite at **K**.

5. If there is no record of the proper resistance how is the fault located?

There are two cases. First suppose the two lines, when both are perfect, to be of equal resistance. First ascertain the resistance of the loop as in question four. Next put the negative wire to the ground as in fig. 49.

The current as before will pass from **B** through the key and divide at *a* and on leaving the galvanometer the two branches will go to right and left and *meet at the fault* **F** both returning to the battery through the ground from **F** to **G'** and

Fig. 49.



B, the wires which cross at **K** not touching each other. Resistance enough is put into the faulty wire by means of the rheostat **R** to make the needle balance. This resistance must

of course equal that of the small part of the loop from **F** through **S** to **D**. The points **D** and **F** being equi-distant from the station **S**. Therefore, half the resistance which we have added in order to make the needle balance, is the distance in ohms of the fault from **S**.

Suppose the resistance of the perfect line is recorded at 100 ohms, and that of the faulty one when perfect at 98 ohms. If now the fault should be 22 ohms from **S**, it is evident that the resistance on the perfect side of the loop from the galvanometer around to the fault is 122 ohms; while on the rheostat side of the loop it must be 46+76 ohms, because 98—22 =76, and we must add 46 more to make up 122, before the needle is balanced. From the 46 added, take 2 ohms, which is the excess of the perfect line over the other, and we have 44. One half this is 22 ohms=the true distance in ohms of the fault from **S**.

6. How may we find the distance of the fault from the operator directly?

We may add all the resistances together 122+76+46=254, and one half this is the distance in ohms of the fault from the galvanometer over the perfect line. This same quotient (122) minus 46, the resistance added, and minus 2, the difference of the two lines, gives 74 the distance in ohms of the fault from the galvanometer over the bad wire. This divided by the resistance per mile gives the number of miles.

7. What is the object of referring to the recorded resistance?

The recorded resistance *taken with the ground wire on* when divided by the number of miles gives the resistance per mile.

8. Is the resistance per mile the same when there is an escape?

Even perfect contact of both ends of a break with the earth will not alter the resistance of the loop since the current has to traverse only a few feet of earth which offers no resistance and then resume its place on the wire. Much less will an escape effect it.

9. What better is the record than a new test?

The record will tell whether the two halves of the loop have the same resistance or not. While a test taken when the loop is made will necessarily make them alike. The error from this source is small.

10. In what case is the record indespensable?

In case one end of a break is left in the air while the other makes earth no current will come through a loop. But the record giving the sum of the two resistances is as good as if we had a loop. Then testing each end of the loop the one in the air will give a very high resistance and the other will give a resistance which at once reveals its distance in ohms from the break.

11. Suppose both ends of a break are left in the air?

If both ends are insulated, then both the perfect and the faulty wire, when the loop is joined at **S** will show high resistance and thus reveal the fact. We must now compare the recorded resistances of the two wires *when insulated* with the resistance which each side of the loop now offers.

In this case it is only necessary to divide the resistance of one mile by the greater of the two resistances given by the different sides of the loop.

12. Give an example?

Suppose a loop 200 miles long has a resistance 5,000 ohms, that is one megohm per mile. On trial, one side of the loop gives $8333\frac{1}{3}$ ohms resistance. The other side gives 12500. Dividing 1,000,000 by 12,500 we have 80 the distance of the fault in miles.

If we divide 1,000,000 by $8333\frac{1}{3}$ we get 120 the distance of the fault measured over the perfect side of the loop.

RULES.—These results for convenience are embodied in a briefer form. The two following rules apply when the broken ends of a wire make earth, or when there is an escape only; and when both halves of a loop have the same recorded resistance:

Rule 1. One half the difference of resistance between the perfect side and the faulty side of the loop, divided by the resistance per mile, equals the distance of the fault from the station where the loop is joined.

Rule 2. One half the sum of all the resistances in circuit divided by the resistance per mile of the loop and subtracted from the whole loop is the distance of the fault from the operator.

When the recorded resistances of the parts of the loop differ.

Rule 3. Subtract the resistance in the rheostat from the resistance of the loop. Half the remainder divided by the resistance per mile of the loop is the distance of the fault.

When one of the broken ends is insulated and the other not.

Rule 4. Find, by the galvanometer, which side gives a low resistance. Divide that resistance by the resistance per mile. The result is the length of that part of the loop between the operator and the fault. Or:

Rule 5 Divide the recorded resistance per mile of insulated wire by the resistance of the insulated part of the broken wire. The result gives the length of that wire in miles between the instrument and the fault.

13. Examples for practice.

1. A loop 80 miles long has a resistance of 960 ohms, the two halves being alike. The rheostat needs 288 ohms to make the resistance of the faulty side equal to that of the perfect side. Required the location of the fault.

Ans, 28 *miles from* A.

2. Loop 160 miles, recorded resistance 1920 ohms, difference of faulty and perfect side 336 ohms. Required the location of the fault. *Ans.*, 66 *miles from* A *or* 14 *from* S.

3. Loop 40 miles, recorded resistance of perfect side 260 ohms, do of faulty side 250 ohms. The needle balances between the faulty and perfect sides of the loop when 51 ohms are inserted. Required the location of the fault.

Answer, 18 *Miles from* A.

OPERATION.

Resistance of Loop - - - - - -	510
" " Rheostat - - - - -	51
Difference - - - - - - -	459

$510 \div 40 = 12.75$ the resistance per mile.

$$\frac{459}{2} \div 12\text{-}75 = 18, \text{ Ans.}$$

(Examples for practice.)

Ex. 4. A loop of 120 miles lying west of A. has a recorded resistance of 1440 ohms, and 96 ohms are required in the rheostat to balance the needle. How far is the fault from A.

Ans. 56 *miles.*

Ex. 5. A loop of 180 miles lying west of A, has a record of $5555\frac{1}{2}$ ohms (insulated) resistance. A break with one end grounded and the other insulated has a resistance on the insulated portion of 11626.7 ohms. On which side of the break is the wire grounded? How far from **A** is the fault?

Ans., On the east side. 86 miles from **A**.

Ex. 6. A loop whose record is 12 ohms per mile uninsulated and one megohm per mile insulated, requires 360 ohms to balance singly the faulty side of the loop and 29720.97 ohms to balance singly the perfect side. 1. What is the nature of the fault? 2. How far is it from the station **A**? 3. How long is the loop?

Ans. 1. A break with wire aground on the faulty side. *Ans.* 2. 30 miles. *Ans.* 3. 67 miles.

7. A loop west from **A** has a record of 1,200,000 ohms per mile and a total resistance of 20,000 ohms. The southern branch requires 10,859.7 ohms to balance the northern which gives 46,153.8 ohms.

1. On which branch is the fault? *Ans.* **N**.
2. What is the nature of it? *Ans.*
3. How far is it from **A**? *Ans.* 26 miles.
4. How long is the loop? *Ans.* 60 miles.

Ex. 8. The recorded resistance of an 80 mile loop is 18 ohms per mile. The loop test, however, gives a resistance of 1300, while the differential test requires an addition of 130 ohms to the faulty side.

1. What is the fault? *Ans.* Break with partial earth.
2. Where is it? *Ans.* 36 miles off.

Ex. 9. A wire out of Albany has five stations distant respectively 7, 17, 24, 33 and 42 miles from **A**.

This wire has a resistance of 13 ohms per mile. A parallel wire through the same stations has a resistance of 12,75 ohms per mile. A test shows a resistance on a certain day of 1344 ohms for the loop, and a differential resistance of 288 ohms. Required, the nature and location of the fault.

Ans. Bad connection at the fourth station.

Solution. We know it is a bad connection of some sort because the resistance is *more* than ordinary. Now the sum

of the resistances 1344+288 divided by 2 and by 16, the average resistance, gives 51, which taken from the whole loop leaves 33 the distance of the fourth station from Albany.

6. *Location of Crosses by Measure.*—1. What is the simplest case of this fault?

The cross easiest to locate is one in which the two wires make a good contact so as to form a loop. We have then merely to make the loop perfect by opening the key beyond the fault on both wires, and then to measure the resistance of the loop. This divided by two and by the resistance per mile will locate the fault.

2. Suppose the contact is not perfect?

If we have reason to suspect there is *résistance* where the cross is made, then each wire should be tested by the loop method with a third wire which is perfect. While one of the cross-wires is being tested the other should be grounded at both ends. The tested wire will then make ground through the cross, and the location may be found exactly as if the cross were a break, with imperfect ground at the broken end.

3. What is Culley's method?

In an extremely neat method given by Culley the differential galvanometer is employed as follows (Fig 50:)

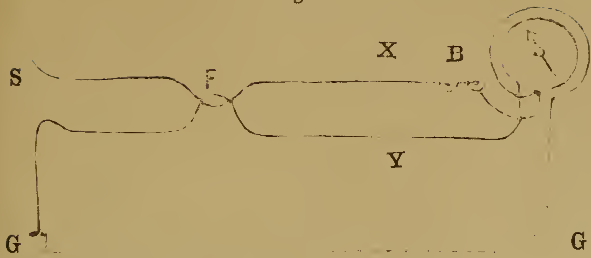
Let **X** and **Y** be two wires which cross at **F**. **S** is a station beyond the fault. Connect the carbon of the battery **B** to the wire **X**, and the zinc to the galvanometer, at the common terminal of both coils. **Y** is connected with the galvanometer, and the distant end is grounded. The remaining terminal of the galvanometer is also grounded.

The current will divide at **F** one branch of it going on to **S** where it reaches the ground and returns through the earth to the galvanometer and battery.

The other branch of the current returns over **Y** from **F** and traversing the other coil of the galvanometer reaches the battery.

Now as the earth makes no resistance if **F** is in the middle of **X** the needle is balanced. If not, the resistance necessary to make it balance will show the difference of resistance of the two sections.

Fig. 50.



4. What is Blavier's formula?

Blavier's formula is as follows:

Let **X** equal the resistance of the shorter portion of **Y**.

" **L** " " of the whole line **Y**.

" **R** " " added to the shorter portion.

Then $X = \frac{L-R}{2}$

Ex. 1. The resistance of a certain line **Y** was recorded at 700, or 14 ohms per mile. On testing for a cross a resistance of 100 ohms was necessary to balance the needle. Required, the distance of the fault. *Ans.* 28,58 miles.

Ex. 2. A wire 40 miles long had a resistance of 13 ohms. On testing for a cross (as in Fig. 50) the needle of the differential galvanometer remained at zero. Required, the distance of the fault.

Give the reason of this answer.

CHAPTER X.

LAW OF RELATIONS.

Note. Hitherto we have explained the methods in use for detecting faults without employing what is known as Ohm's law, preferring to have the student thoroughly familiar with processes of easier comprehension first. The law, however, admits of easy explanation at this stage of the work and may be readily comprehended by one acquainted with the simplest mathematical operations.

1. Electro-motive Force.—1. On what does electro-motive force depend?

With a given battery the force depends on the number of cells in line.

2. What experiment proves this?

Connect a Daniel's cell with one coil of the differential galvanometer and insert the whole resistance of the rheostat in the circuit. A very small deflection of the needle will be observed. Now add one cell to the battery so as to double the intensity; the deflection of the needle is doubled. A third cell will treble it and so on.

3. How does the size of a cell affect it?

The size is unimportant. A small cell yields the same force as a large one. If a small cell and a large one are opposed to each other no current will pass and the needle is not deflected.

4. How do two or more cells joined as a quantity battery affect the needle?

The quantity battery is the same in effect as a battery of large cells; the force depends wholly onthe number used for intensity.

5. Has quantity nothing to do with the deflection?

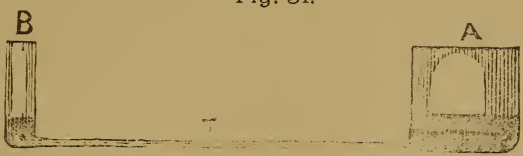
The needle is controlled by the *quantity which traverses the galvanometer wire* and not by the quantity present in the battery. The latter is in a measure static until sent forward by the *force* which we call *tension* and which acts as a spring or pressure to *move* the quantity.

6. Illustrate this by an analagous case of force?

An analagous instance is afforded by two open basins of

water of different size and connected by a tube at the bottom. Let the basins be filled one inch at the same instant and kept supplied to that level.

Fig. 51.



It is evident that as soon as the tube T is filled the pressure is equal throughout and that there will be no current in the tube. Now enlarging either basin of water, or adding others *on the same level* (quantity battery) will create no current. But if we increase the *height* of the water in either basin (intensity) a current at once sets toward the other.

7. How is resistance explained by the same apparatus?

High, insulated resistance is represented by taking off one basin and closing the tube at that end, the pressure (tension) remains, but no current flows in the tube except at the moment of filling it, exactly as it is with a resistance coil or long wire. This tension is proportioned to the number of inches of *height* of water in the basin—corresponding to the number of cells of battery used in electricity.

7. How are other forms of resistance illustrated?

By making use of a long tube and opening the end most distant from the basin, we illustrate the effect of a ground wire (Fig. 52.) The friction offered to the current by the tube, makes a resistance exactly proportioned to the length of the tube and the pressure (tension) inside the tube continually diminishes till at the open end it is zero. Making the tube smaller will diminish the quantity of the current, just as a small wire will transmit less electric force than a large one. Making it longer will diminish the current in the same way.

Every leak will lessen the resistance and drain the force while every stoppage will have the opposite effect, as is the case on a line wire.

8, How is the running of several wires from one battery illustrated?

We are to imagine the water capable of keeping its own level in the basin up to a certain limit. Now if branch pipes

extend from the base, so long as this level is maintained they are all supplied, and if of equal size and length carry the same quantity of water. Change any of these conditions and that branch discharges most which is of largest calibre and shortest length, *i. e.* of least resistance.

9. In branch circuits what is found to be the law of the quantity of electricity passing in each?

The quantity of current passing each branch of any two wires is an inverse ratio to its resistance. Thus if the resistance of one is ten times that of the other, then one tenth as much will flow in that one as in the other, or one eleventh of the whole.

10. What is the rule for finding the *joint resistance* of branch circuits or shunts?

To find the joint resistance of circuits, *multiply tneir resistances together and divide the product by their sum.* Or:

$$J\,R = \frac{R \times R}{R + R}$$

For three or more circuits, find the joint resistance of two and then the joint resistance of *this result* with a third and so on.

11. What is Ohm's law of electric relations?

Ohm's law is that the *quantity of electricity which passes any point in a wire, varies directly as the force, and inversely as the resistance.*

It is expressed by the formula $Q \propto \frac{F}{R}$

If the *units* of force and of resistance have a fixed ratio then $Q = \frac{F}{R}$ *i. e.* The number of farads per second $= \frac{\text{No. of volts.}}{\text{No. megohms}}$

12. How may the formula be varied?

When resistance is constant (*i. e.* a fixed number of megohms) then $Q \propto F$. If F is constant, $Q \propto \frac{1}{R}$ and finally to produce a constant quantity, F must vary as R.

2. *Resistance of Batteries and Short Wires*—1. How is the internal resistance of a battery measured? (See Appendix B.)

To measure the resistance of the battery itself, first send a current through the galvanometer, using the shunt (A, appendix,) so that only 1-100 actually passes; and using no resistance coil, note carefully the deflection of the needle.

Next insert resistance coils between the galvanometer and negative pole of the battery until the needle falls back to its first position. The number of ohms used multiplied by 100 will be the resistance sought.

2. How is the resistance of short wires and office connections found?

To measure the resistance of short wires first find the R of the battery as above, then place whatever is to be measured, in circuit, between the positive pole of the battery and the galvanometer, always using the shunt. Insert resistance coils between the galvanometer and the negative pole. Subtract the resistance of the battery from the whole resistance thus found.

3. When does the resistance of the battery become important?

In all measurements for resistance, that of the battery and office wires traversed should be taken into account, otherwise miles of error may mar the reckoning. But in a *short circuit* the resistance of the battery is of transcendant importance.

4. Why is this?

Suppose a battery has 30 ohms resistance. This is equal to that of two miles of the best line known. But suppose the wire is but a few feet in length the resistance of the battery may be a thousand times that of the wire.

5. Illustrate by experiment.

Clark gives the following curious experiment which furnishes at first an apparent contradiction of Ohm's law. Place the shunted galvanometer in the circuit without resistance coils, and notice the deflection of the needle with one cell. Now add a second cell to the circuit and note the deflection. We have doubled the *force* but the increase of deflection is hardly noticeable. Add a third and a fourth or even five-hundred cells and the needle is not changed.

6. How is this accounted for?

Each cell brings as much resistance as it does force. In other words the resistance, from the shortness of the circuit, being nearly all taken away, the electricity of the first cell escapes before that of the next overtakes it so that no pressure is added.

7. How only can the force become evident?

There must be sufficient resistance to check or dam up the current so that it shall set back as it were and allow the tension of each cell in succession to act on the next following, or to speak less figuratively, a certain portion of the quantity generated must become *static* in order that it may have a base on which to react before its power is revealed.

8. How is this conformed to Ohm's law?*

Suppose the resistance of each cell 30 units and that of the galvanometer wire 4 units, then the quantity for one cell is: $Q = \frac{1}{30+4}$ for three cells $Q = \frac{3}{90+4} = \frac{1}{31}$ nearly; for 500 cells $Q = \frac{500}{1500+4} = \frac{1}{30}$ nearly.

It seems then that the quantity traversing the wire is scarcely changed, and hence the deflection should change but slightly.

9. Does this *static electricity* exhaust the battery?

There is *no waste* of battery by the static portion of the force. When the current ceases to flow on account of *infinite resistance*, *all* the force is static, and the battery remains intact. If a battery capable of yielding 100 farads per second can get away but 60, on account of resistance, then the consumption of 40 per cent of zinc is saved.

3. Practical Application of Ohm's Law.—1. What is the effect of escapes or grounds upon the battery?

Applying Ohm's law Q equals F over R, since escapes *diminish the resistance* of the line the value of the fraction, F divided by R, is increased. A *greater quantity*, therefore, escapes which rapidly exhausts the battery.

2. Is the power to work signals greater or less in wet weather?

Since in wet weather the resistance is less than in dry, more electricity leaves the battery, but being diverted from

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* NOTE. 1000 here has no meaning except as a mere basis of comparison. That is, it is not a *volt* or any other recognized unit of force. A Grove battery which has but 5 ohms resistance would have at most but about 10 volts of force. (Appendix B.) This, to avoid fractions of high denomination may be put at 1000, and then since 1 mega-farad of quantity equals 1 volt divided by 1 ohm, the answers in the following cases if divided by 100 will be in mega-farads, or if multiplied by 10,000 will be in farads. In all cases, Q in mega-farads equals *n* volts divided by *m* ohms; or Q in farads equals 10,000 *n* volts divided by *m* ohms, (See page 85 Q. 10.) If we wish, however, merely to compare the quantity issuing from two different batteries, then an imaginary unit is all that is necessary.

the offices, the working power at any station is *less* than usual. The working power depends upon the *quantity* passing through the instruments.

3. Give Pope's example of finding the working power at a station.

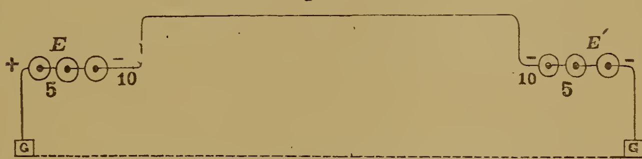
This requires us to find the quantity by Ohm's law. Suppose a well insulated line, **A B** with the ground wires on, has

a resistance of	100	ohms
The batteries 5 each,	10	"
The instruments 10 each	20	"
Total resistance	130	

* Let the force of each battery equal 1000 units.

Then $Q = \frac{2000}{130} = 15.4$ The working power.

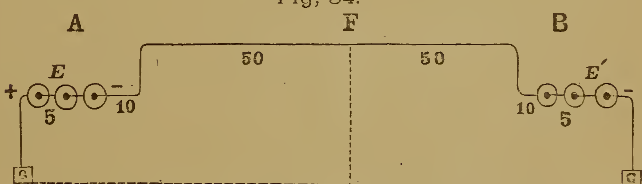
Fig. 53.



4. Suppose an imperfect ground between E and E' which offers a resistance of 50 ohms?

Since the batteries are exactly opposite one another as respects the fault, no effect is produced while the circuit is closed at both **E** and **E'**. When either key is open, however, the effect is the same as if a wire having 50 ohms resistance, extended from the middle of the line to the ground.

Fig, 54.



Suppose **A** opens his key, the circuit from his battery **E** is broken. From **B** there is a circuit around by the fault. Using Ohm's formula $Q = \frac{F}{R}$ we find the working power of this circuit as follows:

Battery resistance,	5 ohms.
Instrument "	10 "
Half line "	50 "
Fault, "	50 "
Total "	115

As F equals 1000, Q equals 1000 ÷ 15 equals 8.7. But on trying the like experiment at the opposite station, **B**'s current. Q' equals 15.4. Subtracting Q from Q' we have 6,7 the working power.

5. What if the fault were near A?

The current from battery **E** would then divide at the fault a part returning by the fault and a part going around by **B**'s ground wire. The resistance will then be as follows: At **A**'s end, the line equals 100 ohms, instrument and batteries equal 15 ohms, total 115 ohms. Resistance of the fault equals 50 ohms.

Their joint resistance is $\frac{115\times50}{115+50}$ equal 34.8 ohms.

To this add resistance of battery **E** and instruments. The total resistance is 49.8.

Q, therefore, at battery **E** equals $\frac{1000}{49.8}$ equals 20

6. What portion of the current will go over each branch?

The resistance by one route is 115 ohms. By the other it is 50 ohms. 115 + 50 equals 165. So $\frac{115}{165}$ of 20 will go by way of the fault, and $\frac{50}{165}$ of 20, 6.1 will go over the line to **B**.

The division of the current from **E**' can be found by a mode precisely similar. Thus

Joint resistance of the two branches $= \frac{15+50}{15\times50} =$	11.5
Resistence of line, battery **E** and Insts.	115.0
Total resistance	126.5 ohms

The Q' from **E**' is, therefore, $\frac{1000}{126.5}$ equals 7.9.

The resistance of the two circuits beyond the fault being

15 and 50, 15 parts will go to the ground at **F** and 50 will go around by the instruments.

7. How much current will there be in B's instrument when A is sending?

In sending, **A** will alternately open and close his key. When he closes it the strength of both batteries will reach **B**'s instrument, that is 7.9 + 6.1 equal 14. But when he opens his key he cuts off the current from his own battery, while from **E**' is a force of 6,1.

The difference between 14 and 6,1 is 7,9 which is the available force at **A** to work **B**'s instrument.

8. How much in A's instruments when B is sending?

When **B** closes his key he has the current, which leaves battery **E**, equal to 20, added to his own current, 6.1 making 26,1. But when he opens his key his own current is cut off, and from battery **E** we have 1000 divided by 65 as in the first part of the example, equals 15.4, which taken from 26.1 leaves a working current of 10.7.

9. How large a Grove battery would this imply?

According to the foot note on *p.* 106 this implies a battery power equal to about 6,1 Grove cells. It is ascertained as follows: Dividing the working current by 100 we have ,107 megafarads. Now as Q equals $\frac{F}{R}$ by substituting figures for Q and R, the equation becomes, $.107 = \frac{F}{115}$, that is, F equals $,107 \times 115$, or F equals 12,20 *volts*. One Grove cell is by the table, (nearly) two volts. Q, therefore, equals the quantity sent over a resistance of 115 ohms by a battery power of $12.20 \div 2$ equals 6.1 Grove cells. The power of about 4 cells would therefore be wasted by the supposed fault.

10. What would be the effect of doubling A's battery.

doubling **A**'s battery will double both its *force* and its *resistance*. **F** must be reckoned 2000 instead of 1000 and **R** 10 instead of 5. Proceeding as before the effective current which **A** can use in **B**'s instrument is 12,6, which, as the resistance is now 120, will be the current furnished by seven and a half Grove cells, 15 being employed. **B** would have a current of 13.4 or a little over eight Grove cells.

12. Would it be better to double B's battery?

Doubling B's battery while the fault is near A, will increase the working power from B through A's instruments, but give A less power through B's instrument.

12. What three practical results have we then?

1st. When batteries and instruments are equal at each end of the line, a fault midway between them does most mischief.

2d. The station farthest from the fault gets the weaker signals.

3d. The increase of battery should be made as near the fault as possible.

13. How are the main batteries usually placed?

Half the main battery is usually placed at each end of the line, unless one end is necessarily more defective than the other.

14. Why not place all the battery at one end?

There are always more or less escapes and a battery wholly at one end, therefore, works unevenly.

15. Why not put it in the middle?

It is essential that the terminal stations have control of the current. If the line were faultless and sure to remain so the location of the battery would still be at these stations.

4. *Blavier's Method Without a Loop.*—1. What occasion may render the loop test impossible?

There is sometimes but a single line, or if there are many, the prostration of a few posts may render them all faulty at once.

2. What merit has Blavier's method?

Blavier's method is quickly and easily accomplished, and requires but one skilled operator. An assistant of ordinary intelligence being sufficient at the distant end.

3. What data are necessary.

Three things must be known:

1st. The ordinary (uninsulated) resistance, (R,) of the wire from the records.

2d. The resistance (S,) of the faulty line (uninsulated.)

2. The resistance (T,) of the faulty line, insulated at the distant end.

4. Suppose R, S and T are known what is Blavier's rule.

RULE. Square S, multiply T by R, and add the products. From this sum take T times S, and also R times S. Extract the square root of this remainder and take it from S. This gives the resistance of the portion between the station and the fault. It is reduced to miles by simply dividing it by the average resistance per mile.

5. Give the same rule in a formula.

Putting **D** for the distance of the fault, and **A** for the average resistance of the line per mile when not faulty, the equation is as follows;

$$D = \frac{S - \sqrt{S^2 + TR - TS - RS}}{A}$$

6. Illustrate the rule by an example.

Ex. Let R, from the record, be 100 ohms, with an average of 12 ohms per mile.

Let S by measurement equal 92 ohms.

" T " " 64 "

Substitute these numbers for the letters they represent in the formula and we have.

$$D = \frac{92 - \sqrt{8446 + 16400 - 15088 - 9200}}{12} \text{ equals } 5\tfrac{2}{3} \text{ miles.}$$

Ex. 2. A line from Haverhill to Lyme, 17 miles has a record of 204 ohms, or 12 to the mile. A measurement for a fault gave a resistance of only 180 ohms, when the line was uninsulated, but when the ground wire was taken off at Lyme The resistance at Haverhill was 320 ohms, where was the fault?

Ex. 3. A line from Hanover to Windsor, ten miles, has a record of 130 ohms. A certain measurement made at Hanover gave only 100, but when insulated at Windsor, it gave 200. How far from Hanover was the fault?

4. A line from Oberlin to Wellington, 8 miles has a record of 126 ohms, or 14 per mile. One measurement, however, gave 100 ohms, with the ground wire on at Wellington or 156 with it off. Locate the fault?

Ex. 5. A merchant in New York has a private line running 8 miles to his country residence. The average resistance is $12\frac{1}{2}$ ohms per mile. A test, however, gives 81.25

ohms, while the test for high resistance (insulated) gives the same. Where is the fault? What is its nature?

In this case, as the high resistance only equals that obtained with the ground wire on, it is evident there is a total escape, or ground, at 81.25 ohms distance; this divided by 12.5 gives 6.5 miles, the *Ans.*

Ex. 5. An organ builder in Boston has a wire from his sales-room in that city to his factory at Cambridge, 10 miles out. The recorded resistance is 130. A test at Boston gives but 100. The insulated test gives also 100. Where is the fault?

CHAPTER X.

CONDUCTIVITY.

1. What is the meaning of this term?

Conductivity is the opposite, or the reciprocal, of resistance. A wire which has twice the resistance of another has but half the conductivity, and *vice versa.*

2. Give an example.

From Table III., appendix, we find that silver has five times the conductivity of brass. We infer that a brass wire of a given size will offer five times as much resistance as a silver wire of the same size and length.

Illustrate by two iron wires.

One mile of No. 9 galvanized iron wire offers a resistance of 16 ohms. No. 4 offers 7,8 ohms. No. 4 has, therefore, a conductivity nearly twice as great as No. 9.

4. Does conductivity depend on surface or weight?

In wires of the *same metal* and *same length*, conductivity varies as the *weight.* If the length varies then *conductivity varies as weight divided by the square of the length, or* $C \propto \frac{W}{L^2}$

5. How long a No. 4 wire will have the same conductivity as a mile of No. 9 wire?

According to the answer of question first, conductivity is

inversely as resistance. The length should, therefore, be 16 ÷ 7.8, or 2.05 miles.

6. **If several circuits drain one battery how is their joint conductivity found?**

The joint conductivity of several circuits is found by adding together the fractions, $\frac{W}{L^2}$ Which express the conductivity of each.

7. **How do heat and cold effect conductivity.**

The colder a wire is the better its conducting power. Heat increases *resistance* at nearly a uniform rate at ordinary temperatures. At the melting point it is enormously increased.

8. **Compare Silver and Mercury.**

Mercury, which is liquid at ordinary temperatures has a conductivity of only 1.6, silver being rated at 100. Mercury solidifies at 40° below zero, and at that point suddenly attains a much higher conducting power.

9. **What is said of the conductivity of alloys?**

The conductivity of alloys is much less than the *joint* conductivity of the metals which compose them.

10. **Of what are resistance coils made?**

Resistance coils are commonly of German silver, which has a very high resistance and is less affected by changes of temperature than most metals or alloys.

Standard coils are, however, made of an alloy of silver one part and platinum two.

11. **How much are the common coils affected by heat and cold? (Table 4, appendix.)**

A german silver wire which has 10 ohms resistance at 32° Farenheit will have at 70°, which is the ordinary temperature of the office, a resistance of 10.812 ohms.

12. **How is this made out from table 4 ?.**

The right hand column of the table gives .024 as the variation for each degree of temperature. From 32 to 70 degrees is a change of 32 degrees, so that $38 \times .024 = .812$ is to be added to 10 giving 10.812.

13. **What standard of conductivity is commonly used?**

Pure copper (99.9) is usually put at 100 and used as the standard in place of silver.

14. **What is the *relative* conductivity of the best commercial copper?**

Wire made of carefully selected copper, such as is used for

7

relays, usually has about 90 per cent of the conductive power of pure copper. A little alloy of lead or arsenic greatly reduces its value for telegraphic purposes, so that ordinary copper wire has not much above 40 per cent the conductivity of the pure metal.

15. How is a *standard* found? or how do we get a basis for comparison?

By experiment with the purest copper, a single pound of metal drawn to the length of one nautical mile (2029 yards) of wire, has a resistance of 1155,5 ohms at 60 farenheit.

Now if the wire weighs 10 lbs. to the mile its resistance is one tenth as great, and so in proportion for any other weight.

16. What small unit is taken for the standard of conductivity?

One inch of pure copper wire weighing one grain is the standard wire.

17. Give its resistance and its conductivity?

The resistance of this unit is .001516 ohms. Its conductivity by the formula $\frac{W}{R \times L^2} = \frac{1}{.001516}$

18. From this how do we deduce the conductivity of any other pure copper wire?

Rule I. The conductivity of pure copper wire of any size and length will be *weight in grains divided by* .001516 *ohms, and by the square of the length in inches.*

19. How can we also find the *resistance* of pure copper wire?

Since resistance is the reciprocal of conductivity, rule 1st., inverted gives resistance. Hence,

Rule II. *The resistance of pure copper wire of any length or thickness is equal to the product of* .001516 *by the square of its length in inches, divided by its weight in grains.*

That is $R = \frac{L^2 \times .001516}{W}$

20, In rule 1st. Why divide by the square of the length?

Suppose the wire one inch long and of one grain weight, to be stretched to two inches. Now its resistance from *length alone* is twice as great as before. But it is also only half as large, which fact again doubles its resistance. In other words each inch of it will now have twice the resistance it had at first and there are two inches. It has, therefore four times its

NOTE.—1 pound Avoirdupois = 7000 grains Troy.

8*

original resistance. If stretched to three inches its resistance would be nine times as great.

21. In selecting wire for a relay or galvanometer how is it tested?

Rule III. To test a wire. 1st. *Find its resistance by a galvanometer and resistance coil.*

2d. *Find what its resistance should be if it were of pure copper*, by rule II.

3d. *Divide the first of these results by the second. The qvotient is the conductivity.*

Ex. 1. A helix containing 5000 feet of copper wire weighed 4 pounds. Its resistance was 22 ohms, what was its conductivity? *Ans.*, .886.

Ex. 2. A certain relay contains 1000 feet of copper wire whose weight is 3-7 of a pound. The galvanometer gave its resistance at 8.084 ohms. What is its conductivity? *Ans.*, 75.

Ex. 3. A helix was purchased for a relay' Its wire was 500 feet long and weighed 2 and 2-7 ounces. Its resistance was 36.64. What was its conductivity? *Ans.*, 50 per cent.

2. *Testing a Line Wire for Conductivity.*—1. On what basis should a line wire be tested?

As line wires are almost universally made of galvanized iron, a convenient basis is the one already given; 16 ohms resistance for one mile of No 9 wire, or 13.5 ohms for No. 7 wire, and 7.8 ohms for No. 4. Or, copper may be still used as a standard; the resistance of the best galvanized iron being taken at one-seventh that of pure copper.

2. Describe the test?

A convenient section of from 10 to 20 miles examined with ground wires on, but all instruments at intermediate stations are detached. The finest weather is to be selected and the mean of many observations recorded.

3. Why are so short lengths taken?

In a long section faults of an opposite kind might occur, *e. g.*, an escape in one place and a bad connection in another and the resistance might appear to be right. Examination of short section is more likely to detect all faults.

4. Suppose No. 9 wire gives just 16 ohms per mile on a section twenty miles long, what would be inferred?

No telegraph line will give the full resistance belonging to the wire unless there are bad joints. We should suspect a line that is too perfect!

5, What is a good average conductivity?

Ninety per cent is regarded as a good normal average on well insulated lines in dry weather. This would be 14 ohms per mile on No. 9 wire. If a higher average can be secured by perfecting the insulation, so much the better.

7. What rule will apply to all lines?

Rule IV. *The resistance of each mile of galvanized iron wire at* 60 *degrees Fahr. is found with sufficient exactness by dividing* 360000 *ohms by the square of* the *diameter. The diameter being given in mils i. e. thousandths of an inch.*

3. *Testing the Instruments.*—1. How is this test made?

All instruments should be tested when new and perfect and the resistance and per cent of conductivity recorded. At any subsequent examination, after the naked line is tested, the instruments one at a time may be put in the circuit and the No. of ohms unplugged in the rheostat on their account will show whether they are in perfect order or not. Where it is practicable they should be frequently tested independently of the line.

2. What rule is used in these tests?

As the instruments are all made of insulated copper wire, Rule III, in this chapter, will give their conductivity. Their least resistance being known, however, mere inspection will give their conductivity.

3. Illustrate by a case?

Ex. 1. A relay when purchased had a conductivity of 90 per cent, with a resistance of 8 ohms. A subsequent test showed 12 ohms. This at once reveals that its conductivity is $\frac{8}{12}$ or .75 of what it should be.

4. How near to pure copper is it now?

It has now 75 per cent of 90 per cent, which is $67\frac{1}{2}$ per cent of the conductivity of pure copper.

Ex. 2. A sounder, when perfect, had 5 ohms resistance, its conductivity being .91 that of pure copper. After continued use it had a resistance of 7 ohms; what was the probable defect? What was its conductivity?

Ans., .65 that of pure copper, or .714 of what it should be.

Ex. 3. A relay with a conducting power of 90 per cent had 7 ohms resistance. A subsequet test showed but 6 ohms What was the probable defect? What was its conductivity?

Ans., to last. Its apparent conductivity is now 1.25 that of pure copper, an absurdity which the nature of the fault will explain.

Ex. 4. At 60 degrees Fahr. what should be the resistance per mile of a line wire whose diameter is 300 mils? See rule IV. *Ans.* 4 ohms.

Ex. 5. At the same temperature what should be the resistance per mile of a line wire whose diameter is 120 mils.

Ans. 25 ohms.

Ex. 6. What is the proper resistance of a line wire whose diameter is 400 mils, when the temperature is 90 Fahr. The resistance of iron changes .35 per cent for each degree of temperature.

Ex. 7. What is the proper resistance of the same wire at 16 degrees Fahr.

CHAPTER XII.

THE LINE.

1. What are the essential parts of the telegraph line?

Outside the office the line consists of three essential parts, the *poles*, the *insulators* and the *wire*.

2. What material should be used for poles?

Thoroughly seasoned wood of oak cedar, hemlock or spruce is best. They should be pealed and seasoned under cover if possible, and always separated by sticks while drying.

3. Should the poles be non-conductors?

The poles need not be insulaters. Iron would be a good material. The English wind a wire down the pole to the ground to prevent "ciphering" or leakage of current from one wire to another. An escape is less annoying than a cross.

4. What if seasoned poles cannot be had?

In case green poles only can be found, they should be stripped of their bark and the lower ends baked or charred, but never covered with tar, as this confines the sap and hastens decay.

5. How should they be set?

The butt ends should be charred six feet, and then set perpendicularly in the ground, not less than five feet deep, and as near a straight line as possible, to prevent strain. In curves the pole should always lean against the strain of the wire. If possible, keep the line on the *inside* of railway curves, both for the sake of economy and safety.

6. Is it better to paint the poles?

If the poles are thoroughly seasoned through, it is best to paint them, but it requires nearly a year to accomplish this. Generally poles had better stand a few months before painting.

7. What is the best size?

They should be at least five inches in diameter at the top

and from fifteen to twenty feet in length; according to the situation; the taller poles being necessary in low places.

8. How many poles are required to the mile?

They are usually set one hundred and seventy-five feet apart, which requires thirty to the mile, but this varies with the quality of the wire and the straightness and level of the line. The more crooked and uneven the ground the more poles are required. On straight; level lines twenty to twenty-five will do.

1. Insulators and Crossbars.—1. What size and length are required for crossbars.

The crossbar should be two inches by four, of tough wood, the upper edges beveled off, and long enough to keep the wires not less than two feet apart. Three or even four feet apart is still better, but this is often an impracticable distance where there are many wires on one set of poles.

2. Why is it better to keep them far apart?

Wires near together are very apt to form crosses, and if they are less than two feet apart, secondary currents may be formed, especially on main lines with large batteries.

3. How are the crossbars fastened?

The bars are let in to the pole an inch, and bolted through or heavily screwed. They should be made so strong as to stand the strain when a wire on one side of the pole is down, and the balance is thus lost.

4 What are the insulators?

The insulators are the glass or other insulating projections attached to the poles and crossbars to prevent the escape and intermingling of currents.

5. How is insulation in tunnels, or under ground affected?

Insulation at the points of support merely, is insufficient in tunnels and damp places. In such cases the whole wire is covered with gutta-percha or vulcanized rubber as ocean cables are.

6. What are the greatest hindrances to in ulation?

Moisture, soot. or dust deposited on the surfaces of the insulators form a conducting medium and occasion leakage, ciphering and great waste of power. Especially in the cities these causes are usually active.

7. What is the first requisite in a good insulator?

The first requisite is of course that it should have a very high resistance—infinitely high if possible—glass, porcelain, vulcanite, compositions of coal tar, and stoneware saturated with parafine are reckoned among the best practical materials for this purpose.

8. What else is to be taken into account in selecting materials?

1. The surface of the insulator should repel water and the material should not be porous so as to absorb moisture.

2. It should not crack or change by the weather, or from the sun's influence.

3. It should have as great strength as possible, to endure either a stretching or a crushing strain.

9. How do the materials mentioned compare in these respects?

Vulcanite is the best insulator, is the strongest and repels water, but does not endure the weather so well as glass, or the composition. Glass is most used, though weak and not repelling water. Perhaps the last mentioned combines the the most of these excellencies. (Q. 7.)

10. What *form* and *size* is best?

The diameter should be as small as strength will allow, and the length should be as great as convenient, because the resistance is increased by both these circumstances.

Fig. 55.

The form (Fig. 55) should be such as to allow the least deposit of snow or rain or dust, and yet to admit of secure fastening to the wire and supporting pin.

11. How is the glass sometimes supported?

In the *Wade* insulater the glass is protected by a wooden shield which has been thoroughly saturated with hot coal tar. The glass is cemented by a non-conducting substance.

12. How is hard rubber used?

Hard rubber or vulcanite is sometimes used to cover an iron hook and then the whole set into a cavity in the lower side of a crossbar. Glass is sometimes used in the same way.

13. How is the paraffine insulation secured?

In *Brooks'* stoneware insulator, (Fig. 56) a stone cap is saturated with paraffine and screwed to an iron pin which is itself screwed into the crossbar or bent up and screwed directly into the post. This affords a far better insulation than any glass cap, and is cheap.

Fig. 56.

14. What precautions are necessary in fastening the insulaters?

If the *bracket* is used, its shoulder should be cut away, leaving an edge on the upper side so that rain will not spatter up under the insulator, and snow will not accumulate. The edge of the insulator must be at a considerable interval from the bracket, else in a rain storm continuous connection with the ground is formed by the water.

15. How is it on a crossbar?

The upper surface of the crossbar is made sharp for a like reason unless suspension insulators are used.

16. To what liabilities is the insulator subject?

The wind sometimes lifts the wire and the insulator is carried off the pin. In crossing a valley where the posts are not up to the general level, the strain of the wire, especially in cold weather will often lift them in the same way.

17. How is this prevented?

The stoneware insulator (Fig. 56) is not liable to these accidents unless the strain is so great as to break it. If other insulators are used, a few suspension hooks which are attached below the crossbar should be provided.

2. *The Line Wire.*—1. What are the desirable qualities in the line wire?

A line wire should combine strength, lightness and high conductivity as far as those are compatible. Cost is of course an important element; but a slight difference of cost will not compensate for a large sacrifice of these qualities.

2. What metal combines them best?

By a glance at Table III in the Appendix it will be seen that steel and zinc though far inferior to copper are each better than iron. Coating iron or steel with zinc is different from making an alloy and rather increases conductivity,

while protecting from rust. Coating with copper will do the same in a higher degree. Steel covered with copper is best.

3. How does the latter compare with galvanized iron?

A wire of steel, copper sheathed, of No. 14 size, has as high conductivity as No. 8 galvanized iron, and weighs only about one-fourth as much. It has greater tensile strength than the iron and costs less.

4. Why is it not more used?

It needs only to be known to be more extensively employed.

5. Is it good economy to use small wire?

By using *large* wire, and consequently high conductivity, a line may be worked with fewer cells; and the tension being less, there is less loss from escape, and every instrument works more freely. It would be far better economy to use a steel wire as large as No. 10 than a smaller size.

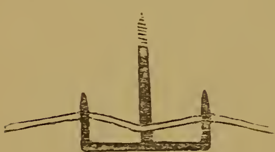
6. How is the wire protected in cities?

On account of the gas from burning coal and other causes the wire used in cities corrodes easily and should be painted before it is put up, especially if galvanized with zinc.

7. How is the wire attached to the insulator?

The wire should not be bent around the neck of the insulator as this would crush the glass, but should be laid in the grove at one side and fastened by a separate wire. Bending the wire abruptly also injures the continuity of its surface and lengthens the line. Some insulators require no tie wire; the fastening is made by slightly bending the line in and out of an inverted T shaped hook as in Fig. 57.

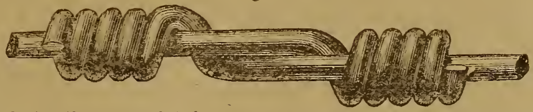
Fig. 57.



8. How are two wires spliced?

The wires should never be joined by looping together, but they should just lap by each other a few inches, and then each end should be tightly wrapped around the wire, (Fig. 58,) and cut close, leaving no loose ends to hook or catch any thing.

Fig. 58.



9. Is the joint then complete?

No joint is complete till soldered. Rust or wear is sure to cause great resistance unless this precaution is taken.

10. How is the soldering done?

A solution of chloride of zinc with a little muriatic acid, is put on the joints till it wets all parts of it. The whole should then be heated over a coal furnace till it is at the melting point of the solder, a slender rod of solder is then rubbed along the joint which will be instantly and thoroughly filled with it.

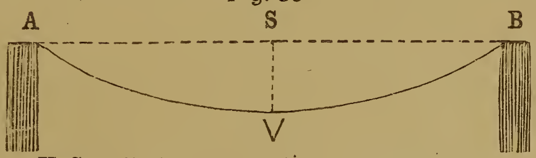
11. What precaution is to be observed?

The wire should not be overheated, but should be *felt of* by touching it with the solder as it approaches the proper temperature. If copper and iron are connected the chloride of zinc should be washed off and the wire protected with varnish to prevent galvanic action between the metals.

3. ***Strain of the Wires.***—1. How nearly straight should the wires be drawn?

In Culley's Hand-book, the proper dip for a span of 80 yards, in mild weather, is given as 18 inches below the level.

Fig. 59.



That is **V S**, called the *versine*, (in Fig. 59,) is 18 inches when **A B** is 80 yards; with No. 8 wire this causes a strain of 420 lbs, the breaking strain being 1300.

2. Suppose the span is less than 80 yards?

The same wire with a span of 60 yards should have a versine of $10\frac{1}{8}$ inches. It is found as follows: Putting **L** for length of span, and **V** for versine, the rule is, $L^2 : l^2 :: V : v$. Taking the numbers given we have $80^2 : 60^2 :: 18 : 10\frac{1}{8}$.

3. Does the weight of a wire make a difference?

If the wires are of different sizes the strain varies directly as the weight and inversely as the versine. Or $S \propto \frac{l^2 \times w}{v}$

and the strain should never exceed one-third the breaking strain. (See Table IV, Appendix.)

4. **Where is the strain greatest?**

The strain is greatest at the point of suspension, but only by the weight of a wire equal in length to the versine which is unimportant.

5. **What rule will give the proper dip for good wire of any weight for any span?**

RULE III. Square the span expressed in yards, and multiply this by the number of cwts. in one mile of the wire. Divide by one-third the breaking strain, and by 31.43.

6. **Give Clark's formulas for the comparison of strain and dip.**

Clark's formulas are, strain $= \frac{l^2 \times w}{31.43 \times v}$

and dip $= \frac{l^2 \times w}{31.43 \times s}$

CHAPTER XIII.

OCEAN CABLES.

1. **How are the ocean cables worked?**

Owing to the enormous lenght of the cable, sufficient power cannot well be transmitted to work a Morse register, the mode therefore adopted is to operate a galvanometer needle, and from the movements of the needle signals are received.

2. **What kind of a galvanometer is used?**

A very delicate galvnaometer devised by Thompson is used. It consists of a very light magnet, half an inch long suspended by the thinnest possible platinum wire within a circular helix of many thousand convolutions. The magnet is polished on one side and a ray of light falling on the polished surface, is reflected upon a screen twelve feet distant. The slightest motion of the needle appears thus greatly magnified on the screen.

How is the motion interpreted?

The Morse alphabet is used and its signals are *inferred* as follows: When no current is passing the ray of light settles to a zero mark on the screen. When a current flows through in one direction the ray deflects to the left, and is interpreted as a *dot*, when the current is drawn backward through the coil the needle veers to the right of zero, and this is a *dash*, long or short, according to the time it remains. The needle at zero is a *space*, whose length is determined in the same way.

4. How is the current drawn backward?

To understand the return of the current it must be borne in mind that the cable itself is like an immense Leyden jar, the wire constituting the inside coating and the water the outside. In sending a signal the cable has to be charged up to the potential of the battery. To produce a return current it is only necessary to *partially discharge* the cable.

Fig. 60.

5. Explain the operation of the condenser.

The battery **B** at the sending station is connected with the cable by the back contact of the key at **K**. The cable is therefore kept permanently charged. But upon depressing the key making contact at **I** the cable is connected with the earth at **E**. To effect a complete discharge requires a considerable interval of time. At the receiving end is the reflecting galvanometer **G**. and beyond it is the condenser **C**. At **O** the cable divides and one branch goes through the powerful rheostat **R** and thence to the ground. This gives a constant but very

small escape, reducing the tension in the galvanometer and condenser a *very little* below that of the cable.

Now the first signal must always be made by momentarily depressing the key which reduces the tension of the cable a little below that of the condenser, when a flow of the current backward through the galvanometer takes place turning the reflecting magnet, or point of light to the left of zero. On raising the key, back contact is restored, and the potential of the cable being highest again, the current passes through the galvanometer, turning the magnet in the opposite direction, and charging the condenser as before.

6. What are the advantages of this method?

By this method the cable is never entirely discharged and the balance between the potential of the condenser and that of the cable being very slight, a current may be readily made to pass either way throug the galvanometer.

7. At what rate are signals sent?

By this mode from fifteen to twenty words a minute may be sent by an expert operator. (Appendix D).

8. How does this compare with messages by air lines?

The number of words by air lines has in rare instances averaged forty to forty-five words per minute, when received by sound.

1. Faults in the Cable.—1. By what modes are faults in the cable located?

The methods for locating faults are the same as for air lines:

1st—By direct measurement.
2d—By Blavier's method.
3d—By the loop test when there are two lines adjacent.

2. What method is practiced while the cable is being laid?

During the process of laying the cable the battery is on ship-board and a current is passing through the whole cable, both the portion coiled in the ship and the part already laid. A galvanometer is placed between the battery and cable so that any change in conductivity would instantly be revealed. At the shore end a very high resistance is placed between the cable and the galvanometer, while beyond the galvanometr the wire is grounded. The high resistance allows a feeble current to traverse the galvanometer, keeping its needle permanently but slightly deflected. The resistance is necessary

in order that the tension produced on shipboard may remain nearly static in the cable. Now the slightest leak in the cable produced on lowering it, would instantly reduce the potential at that point, and the galvanometers on shipboard and shore would both be affected by a current setting toward the leak.

3. How is the close watching relieved?

Every fifteen minutes the ship reverses the battery and the effect being observed on shore assures the continuity of the cable to that moment. Other relief is only made by a change of observers.

4. If a fault occurs how is it located?

The tension on shore, on the sea side of the high resistance, is allowed to charge a condenser which remains attached to the cable for ten seconds. The condenser is then suddenly discharged through a separate galvanometer, into the earth, and the tension it had is thus measured, and the result is communicated to the ship. Knowing the tension before and after the fault, the operator on ship-board can calculate its precise position. *

5. If the core of the cable breaks, how is the break located?

During the manufacture of the cable a record is made of the quantity of static electricity that each mile of it can contain. If it break within the gutta percha, still remaining insulated, it is only necessary to divide the number of farads which the broken section can now contain by the average number of farads which each mile contains and the quotient is the distance in miles.

6. How do they ascertain the capacity?

A condenser of known capacity is discharged through the galvanometer and the deflection noted. Then the cable is discharged through the same galvanometer and the amount of deflection it makes is compared with the other.

7. How are cable joints tested?

The cable joint is immersed in a trough of water and a battery is connected with one end of it, the other being insulated by standing out of water. The trough is insulated and if

* NOTE. Clark's formula for this calculation is $T - t : t - s :: R : x$, where T and t are the tensions on shipboard each side of the resistance coils, $S =$ the resistance of the shore end of the cable, and R the whole resistance before the fault occurred. X is the distance of the fault from the ship.

there is any leakage from the cable it is allowed to accumulate in a condenser for a minute or other definite unit of time. The condenser is then suddenly discharged through a galvanometer and the amount of leakage is measured.

This must not exceed that from the same length of perfect cable.

8. **How can the ship communicate with the shore amid all these tests?**

A separate condenser is employed, and by a sudden discharge of it, although the cable seems fully charged, yet pulsations can be sent through it, which act on the galvanometer needle at the receiving end.

9. **How may a cable be minutely examined throughout its length?**

A mile or more of the cable is wound on a drum and a powerful battery connected with one end, the other being insulated. The cable is then slowly wound off onto another drum, a few inches of it always passing through a basin of water. A wire from the water leads through a delicate galvanometer and thence back to the negative pole of the battery. The slightest escape will thus be detected.

10. **Is the perfect cable free from all leakage?**

The best cable shows so much escape by this examination that a provision is made for resisting it. A wet thread is used instead of wire from the basin to the galvanometer, and only the excess of deflection from a fault is noticed.

CHAPTER XIV.

OFFICES AND CONNECTIONS.

Wires entering, or in an office should not touch each other, or touch a communicating metal, though they are supposed to be thoroughly insulated. The insulation may be burned off by lightning, or some accident may abrade it. Nor should the office wire be spliced if it can be avoided, but if spliced it should be soldered. The line wire should be well supported by an insulator at the point where it enters the office and the entrance should be made through a glass or hard rubber tube inclining downward on the outside to keep out rain. Inside the office the line wire should be screwed or soldered to a binding post, from which the copper wires of the instruments lead off to their respective localities.

Fig. 63.

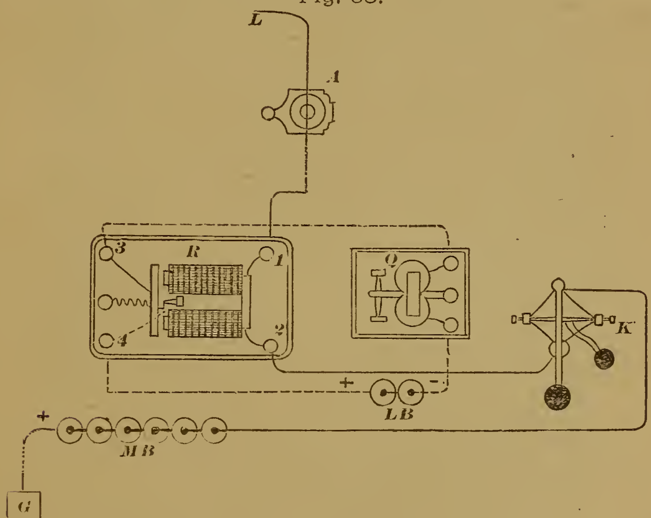
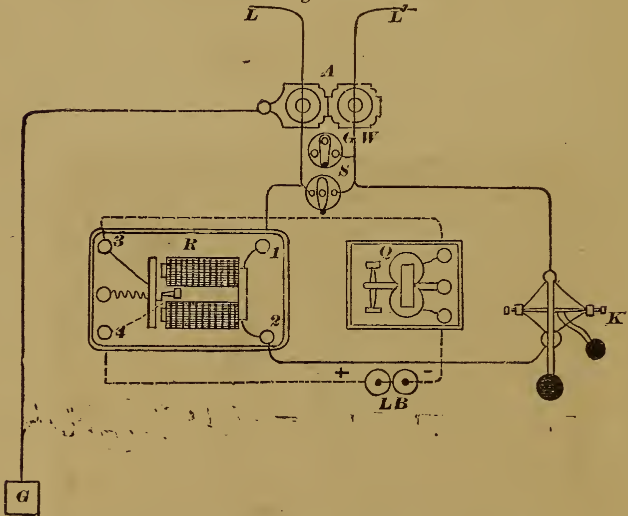


Fig. 63 represents the relative situation of batteries and instruments at a terminal station.

The main line enters at L, passes through the lightning arrester at A, thence to the relay R, through the binding post 1, thence from the relay through the binding post 2 to the key, K, from which it passes through the main battery M. B., to the ground at G. A ground wire also passes directly from the lightning arrester to the ground. The connections of the *main* circuit are represented by the *continuous* line, the *local* circuit by the *dotted* line. The latter passes from the positive pole of local battery L. B., to the relay armature through binding screw 4, thence through 3 to the sounder Q, thence back to the local battery.

Fig. 64.



The arrangement of instruments and batteries at a *way station* is shown in Fig. 64.

The course of the line is from L, through the lightning arrester A, to the relay R, by way of the binding post 1, thence through 2 to the key through the second lightning arrester to the line L'.

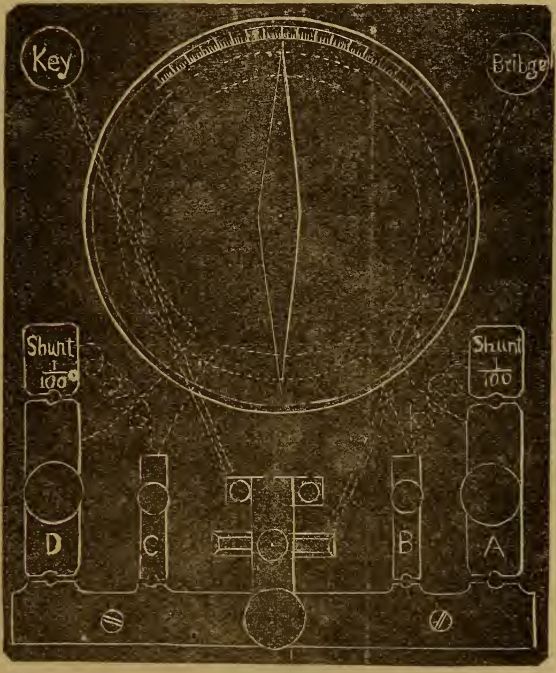
At S is a "cut out," a button switch, which may be so turned that the current will not enter the relay, but will make the short loop L. S. L'. The ordinary plug switch may be made to answer the same purpose,

The ground-switch G. W. is so arranged that either side of the line may be connected with the earth. It is used only in detecting escapes, or when called for by the main office for any purpose.

APPENDIX

A.—Clark's Double-shunt Galvanometer* is a very excellent form of the differential instrument. That is, it is wound with two wires designed to carry currents in opposite directions about the needle. One of these circuits extends from A to B, (Fig. 60) the other from C to D. These wires are both adjusted to have the same electrical resistance and also to have the same effect on the needle, so that when a battery is connected to the two central terminals B. and C. the current

Fig. 61.



divides itself into two equal portions; one flowing from B to

* Clark's Elementary Treatise, *p.* 47.

A and tending to deflect the needle to the right and the other from C to D, deflecting it to the left; but since the quantities and forces are precisely equal the needle remains at rest. If equal resistances are added on each side of the galvanometer the needle still remains motionless, but if unequal resistances be added, more electricity flows to that side which has the lesser resistance and the needle is deflected to that side. The peculiarity of the instrument consists in the addition of a shunt or derived circuit to each half of the galvanometer. These shunts are marked on the instrument "shunt 1-100." They are short wires having a resistance equal to one ninety-ninth that of the half coil, and when thrown into the circuit by the insertion of the plug, ninety-nine one-hundredths of the current pass through the shunts, only *one* one-hundredth traversing the galvanometer. The instrument is supplied with resistance coils varying from one to ten thousand ohms.

B.—The internal resistance of different batteries as ascertained by the nice experiments of Dr. Clark are as follows:

A. Grove's cell offers the least resistance. being usually below 1 ohm per pint cell.

Daniell's from 5 to 10 ohms.

Smee's below 1 ohm, which greatly increases, however, with the deposition of hydrogen bubbles.

Table first gives appoximately, also, the comparative electromotive force of the different batteries.

C.—The Electro-static Capacity of an insulated body is the number of farads it will receive with a unit, or volt, of force. A Leyden jar, for example, may have its inner coating connected with the positive pole of a single Daniell's cell, and its outer coating with the earth. The negative pole of the battery goes also to the earth. The jar will now be charged up to its electro-static capacity, and if the battery be detached, the discharge may be affected through a galvanometer. The force is impulsive and the distance which the needle moves, compared with that which one farad of quantity will move it, will give the capacity of the jar.

The outer coating of the jar all this time exhibits no tension whatever, its force being disguised.

The capacity of the jar varies directly as the amount of coated inner surface and inversely as the thickness of the glass.

D.—Measurement of force. In determining the electro-motive force of batteries it is implied in the answer to question 2, p. 103, that the needle point of the galvanometer will move over an arc exactly proportional to the force. This can be taken as true only when the movement is confined to a small arc of perhaps 15 degree or less, *i. e.* while the needle remains almost parallel with the wires of the helix, unless the force is a mere impulse.

Various devices have been employed to obviate this defect of the galvanometer. One form of the instrument has the needle so suspended that in turning, it shall twist an exceedingly fine platinum wire, which will thus offer a constantly increasing resistance to its motion. The graduated circle is detached so that it can be set in any position, and the helix can be revolved on a vertical axis. As soon as the needle is deflected from any cause, the helix is to be turned with it; thus the force is exactly measured by the number of degrees. For many purposes this instrument is not available. A more skilful device is the "tangent galvanometer." In this, the law of the resolution of forces is applied, the needle being always found in the direction of the resultant. The radius of the circle, or half the length of the needle, represents the force which tends to hold it in its place, while the tangent of the arc it describes, represents the *disturbing* force of the current. The needle when deflected, will occupy the position of the secant of the arc, pointing always to the extremity of the tangent, which may thus be read off on a scale attached, or may be more accurately calculated from a table of tangents.

A simple method much used in measuring the tension and the capacity of a cable is to note the *swing* of the needle from an instantaneous discharge as described above for the Leyden jar.

By this method also, in connection with shunts and condensers the tension of a large battery may be readily determined.

E.—Spontaneous Discharge of the Cable. When the batteries are detached, the cable gradually loses its tension by what is called leakage. This is probably occasioned not by defects or openings in the gutta-percha covering, but by the polarization of the dielectric, which gradually unites the positive of the core with the induced negative of the surrounding water. In other words the gutta-percha is a slow conductor of electricity.

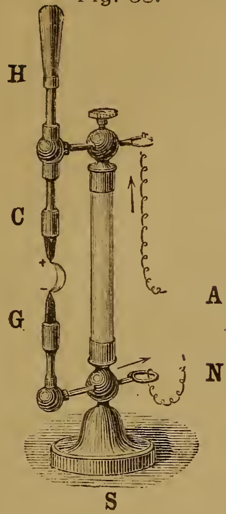
The ratio of this loss or leakage does not vary with the intensity of the charge, but the tension falls from any height at the rate of about 7 per cent of the whole amount present, each minute. That is, seven per cent of the whole charge is lost the first minute, seven per cent of the remainder the next minute, and so on indefinitely. It is easy by successive subtractions of seven per cent to find how many minutes it takes to fall one-half. The higher the tension the longer it takes and thus the battery power may be known.

Latimer Clark institutes direct comparison of the cable tension with that of separate condensers, which are severally charged to the whole tension, 90 per cent, 80 per cent, 70 per cent and so on as far as is convenient. At suitable intervals of time the cable on one side of a galvanometer and the condenser on the other are connected through it by the simple movement of a key. If the cable and condenser are alike no deflection of the needle takes place. If the cable is either above or below the tension of the condenser a slight corresponding deflection will result.

G.—The subject of electric light is one of great interest though not connected with telegraphy. The simplest form of the apparatus for producing the light is exhibited in Fig. 65.

S is a supporting standard having two brass balls separated by a glass rod. Through the upper ball the current passes from A to a brass rod which terminates at C in a carbon point. This rod is moveable up and down by the handle H. At G is a second carbon point which is connected with the wire N. Suppose A and N to be connected with the battery,

Fig. 65.

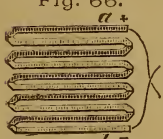


the handle H is pushed down till the carbon points touch. The current is thus established, and as the carbon is a poor conductor, and small at the junction, a great *resistance* is offered at that point, and an intense heat accompanied by light of dazzling brilliancy is witnessed.

The points may now be withdrawn a short distance from each other, to increase the resistance, when an "electric arch" of wonderful splendor plays between the points.

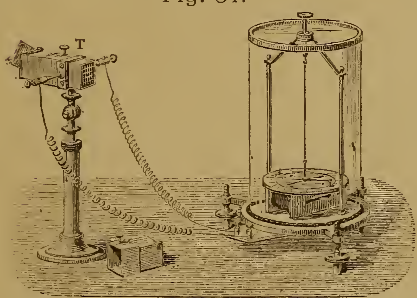
The electric lamp is a contrivance of clock-work by which the carbon points, as they waste away, are kept at a uniform distance from each other.

Fig. 66.



H.—The development of electricity by heat is beautifully shown by the apparatus exhibited in Figs. 66 and 67. A bundle of bars of antimony and bismuth are soldered together at alternate ends as in Fig. 66, and the outside plates, one of antimony and the other of bismuth terminate each in a wire, on applying a gentle heat to one end of the bundle, a current of electricity is at once set in motion from one metal to the other.

Fig. 67.

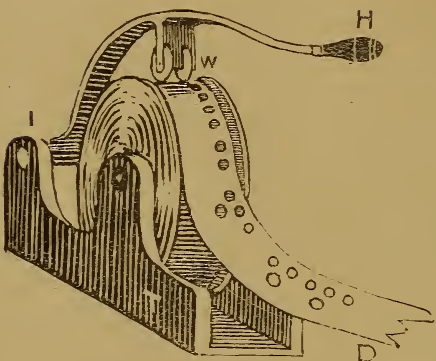


A compact bundle of such plates is seen at T in Fig. 67, and the wire terminals are connected with a galvanometer. On turning the cap, which covers the end remote from the galvanometer, even the warmth of the hand held several feet distant is enough to cause a visible deflection of the needle Such a bundle is called a *thermopile* and is one of the most

sensitive forms of thermometer ever devised. Any current of heated air excites electric action.

I. The Automatic Telegraph.—The object of this invention is to enable any number of operators to receive messages from customers and by a certain arrangement to send all these by one special operator with a rapidity far surpassing anything hitherto known, as rapidly for example as they could possibly be articulated with the organs of speech.

Fig. 62.



The invention is in three distinct parts. The first is a stamping machine, which cuts the message entirely through a strip of paper which has been prepared with paraffine or other substance to render it a non-conductor.

The Machine consists of a box containing a number of cylindrical steel rods of the same diameter as that of the holes to be punched and lying parallel in groves. To represent a dash, *three* round holes are punched, one of which is out of line with the two adjoining, as seen in Fig. 62. The number of rods equals that required by the longest letter. A keyboard in front of the box has the twenty-six letters of the alphabet and the other necessary characters severally printed on the respective keys. On striking any key with the finger, the rods necessary to stamp in the Morse character the letter printed on it, are driven out a short distance from the box and are thus made to perforate the paper. No matter how complicated the letter, a single touch of the key prints it perfectly. The return of the key to its place hitches the paper along exactly enough to make a *letter-space* and a blank key struck at the end of a word gives it an additional motion

equal to a *word-space*. The operator spells the word mentally as he touches the key for each letter, and pronounces it on the blank. By this machine the message can be stamped in the Morse character nearly twice as quickly as it can be written in ordinary scrip with the pen.

The next part of the Invention is the transmitter. This consists of a grooved roller two or three inches in diameter over which the perforated paper is made to pass, Fig. 62

This roller has metallic connection with the positive poles of the battery. Above the paper are two small thin wheels, which stand exactly over the lines of holes, and which are connected with the line wire. Now at whatever rate of speed the paper is drawn under these small wheels it is evident that when either of them runs into one of the holes of the paper it will reach through and make contact between the line and the battery thus transmitting a dot to the other terminus of the line. To make a dash, the hole which is out of the main line of the perforations is made so large that its wheel enters it before the other wheel is out of its hole and continues contact till the other enters a second hole. This contact is maintained as long as is desired, and it is obvious that the paper may be drawn through with a rapidity limited only by the receiving capacity at the other end of the line.

The third part of the invention is the receiver. This consists of a strip of paper so prepared as to be a conductor of electricity and having in it such chemical ingredients that the passage of a current through it will turn the paper black at that point. This strip of paper is drawn over a metallic pully suspended much as the larger wheel of the transmitter is, and which communicates with the negative pole of the battery or with the ground. Above the paper instead of two wheels as in the transmitter, there is a single steel needle point connected with the line. When, therefore, a dot is transmitted the current passes down the needle and penetrates the paper leaving a small black stain, and when the contact is kept up by the two small wheels of the transmitter, a dash is stained on the paper. The paper is drawn through at about the same rate as the perforated paper at the sending station,

the necessary velocity being agreed upon or ascertained by practice. It is not necessary that they be alike. It is only necessary that the receiving paper run off fast enough to render the message legible. It is claimed that by this invention one wire will do the transmitting of five or six stamping machines and that each of these will prepare a message in one-third the time it takes to communicate it in the ordinary way. It is not necessary that those who operate the stamping or punching machine should know the Morse alphabet though the transmitting and receiving operator should of course know it and an ordinary key is always at his command, to make calls and inquiries.

J.—It might be inferred from pages 102 and 103 that a quantity battery would in no case *send* a greater quantity than a single cell. This, however, depends entirely on the amount of resistance offered. The resistance may be so slight that a quantity battery, however large, can send away all the force generated. If, therefore, we diminish resistance in a given case we may always increase the quantity until the capacity of the conducting wire is fully used, and the electric potential will thus be maintained. Whenever the resistance of a wire is greater than that of the battery itself a quantity battery will not avail to increase the force, but if it is reduced and kept below that of the battery, then no matter how many cells are joined up for quantity all the electricity generated will be sent over the wire. For the production of light, heat or magnetism, therefore, short circuits with thick wires are best, and very large cells or many joined for quantity may be used.

It is analagous to a large mill dam with a low or slight fall. The power will still be great if the flume and buckets are very capacious so as to receive all that can be supplied.

In case of a leak or escape the resistance of a line is diminished, and if we wish merely to keep up the original tension we have only to increase the quantity by joining up the cells into a quantity battery. We can of course supply it by an intensity battery, as this will force a greater quantity over the wire, but this will also increase the waste which the other

method will not do. An escape constantly tells on a battery exhausting its static fund and depressing its tension, below what its average should be.

TEMPERATURE.

The zero of the Centigrade thermometer is the freezing point of water, and 100° is the boiling point of water.

Between these two points a Farenheit's thermometer makes 180°. The centigrade degrees are thus nearly twice as large as Farenheit's, or in the ratio of 9 to 5.

To convert centrigrade temperature into Farenheit's, *multiply by 2, subtract one-tenth and add 32.*

Ex.—A centigrade scale shows 20° above zero.

$20 \times 2 = 40$, and $40 - 4 + 32 = 68°$, the temperature by Farenheit's scale.

JOINT RESISTANCE.

For finding the joint resistance of several branches a rule simpler than that given at page 104 is this. *Add together the reciprocals of the several resistances and the sum will be the reciprocal of their joint resistance.* Thus suppose three branch circuits have a resistance of 30, 60 and 80 ohms respectively; then $\frac{1}{30} + \frac{1}{60} + \frac{1}{80} = \frac{1}{16}$. The joint resistonce is therefore 16 ohms.

TABLE FIRST gives approximately the electro-motive force of the batteries in common use. Thus a cell of a Smee's battery has only one-fourth the power of a Grove cell.

TABLE SECOND gives the absolute power of different batteries as nearly as it can be averaged. Thus a single Grove cell yields 1.927 volts or nearly 2 volts, while Daniell's yields but a trifle more than half as much.

IN TABLE THIRD silver wire is taken as a standard, and the conducting power of a wire of given length and size for several metals and alloys is compared with silver.

For more accurate comparison the resisting power of fluids is given in millions instead of units.

TABLE FOURTH is an exhibition of the amount of *resistance* in wires of different metals given in ohms and fractions of an ohm. The comparison is made either for a fixed weight per foot, or for a fixed diameter and length, the weight varying with each substance. This table also gives the per cent. of variation for temperature.

TABLE FIFTH gives the relative sizes and weights of wire.

TABLE SIXTH gives the different units of measure used in telegraphy.

In the following propositions d represents the diameter in mils (thousandths of an inch.)

IRON.

1. Specific gravity of bar iron, ... 7.7.
2. Weight of one cubic foot, ... 481.25.
3. Breaking weight of common irons

Breaking weight of fine drawn wires, per square inch section, ... 40@50 tons.

(Hard drawn wires, spring temper are toughest.)

Weight per nautical mile (2090 yds.) of iron wire $\dfrac{d^2}{62.29 \text{ lbs.}}$

Weight per. statute mile (1760 yds.) $\dfrac{d^2}{72.15 \text{ lbs}}$

Diameter of wire weighing n lbs. per statute mile, $\sqrt{72.15 \times n}$ mls.

" " " " " " nautical. " $\sqrt{62.59 \times n}$ mils.

Conductivity of galvanized iron wire compared with pure copper. .14.

Resistance of galvanized iron per statute mile at 60 degrees Fahr. $\dfrac{360,000}{d^2 \text{ ohms.}}$

Resistance of No. 8 galvanized iron wire per statute mile 13.5 ohms.
" " 9 " " " " " " 15. "
Increased resistance of iron wire for each degree Fahr. .35.
Copper,
Specific gravity of copper wire, 8.8.
Weight of cubic foot, 550 lbs.
Breaking wt. of copper wire averages to each sqr. inch 17 tons.

Weight per Statute Mile of any Copper wire $= \frac{d^2}{63.13}$

Weight of one mile No. 16 Copper wire, about - - 64.5 lbs.

Diameter of any Copper wire in inches $= \frac{1}{2}\sqrt{\frac{w \text{ (in oz.)}}{b \text{ in inches.}}}$

Diameter of any Copper wire weighing N pounds per Statute mile $\sqrt{N \times 63} \text{ mils}$

Resistance per Statute mile of pure Copper wire at 60° Fahr. in ohms $= \frac{81361}{d^2 \text{ mils}}$

Resistance of No. 16 copper wire per statute mile 19 ohms.

Resistance in ohms of any pure copper wire b inches long weighing n grains $= \frac{001516 + b^2}{n}$

TABLE I.

Grove's	100
Bunsen's	98
Daniel's	56
Smee's	25
Woollaston's (copper and zinc in acid)	46
M. Davy, sulphate mercury and graphite	76
Chloride silver	62
Chloride lead	30

TABLE II.

Converted into volts the table is as follows:

Grove's	1,927 volts.
Bunsen's	1,888 "
Daniell's	1,079 "
Smee's	481 "
Woollaston's	886 "
Davy's	1,464 "
Chloride silver	1,194 "
Chloride lead	578 "

RESISTANCE OF FLUIDS.

Pure rain water	40,653,723,00
Water, 12 parts; sulphuric acid, 1 part	1,305,467,00
Sulphate Copper, 1 pound per gallon	18,450,000,00
Saturated solution of common salt	3,173,000,00
" " of sulphate of zinc	17,330,000,00
Nitre Acid 30 B	1,606,000,00

TABLE III.

M. G. Farmer's table of the conducting power of materials.

Silver	100
Copper pure	99.9
" selected	85 to 95
" commercial	40 to 70
Brass	20
Gold	78
Zinc	29
Steel	16
Iron	15
Tin	12.4
German silver wire	12 to 16
Lead	8.3
Mercury"	1.6
Platinum wire	6.9

TABLE IV.

Name of Metals.	Resistance of wire 1 foot long, weighing 1 grain.	Resistance of wire 1 foot long, 1-1000th inch in diameter.	Approximate per cent. variation in resistance per degree temperature.
Silver annealed	0.2214	9.936	0.377
" hard drawn	0 2421	9.151	.209
Copper annealed	0.2064	9.718	.215
" hard drawn	0.2106	9.940	.202
Gold annealed	0.5849	12.52	0.365
" hard drawn	0.5950	12.74	....
Aluminum annealed	0.06822	17.72	....
Zinc pressed	0.5710	32.22	0.365
Platinum annealed	3.536	55.09	....
Iron annealed	1.2425	59.10	.35
Nickel annealed	1.0785	75.78	....
Tin pressed	1.317	80.36	0.365
Lead pressed	3.236	119.39	0.387
Mercury liquid	18.740	600.00	.04
Platinum silver alloy, hard or annealed, used for standard resistance coils	4.243	148.35	0.017
German silver, hard or annealed, commonly used for resistance coils	2.652	127.32	0.024
Gold silver alloy, 2 parts gold, 1 part silver, hard or annealed	2.391	66.10	0.065

TABLE V.

Table cf the Sizes and Weights of Iron Wire.

B. W. Gauge.	Diam. in Mils *	Per Statute Mile. Weight in lbs.	Weight in cwts.	Resist 'e in ohms	Naut 'al Mile Weight in cwts.	Break 'g weight at 20 ton pr.sq.in· cwts·
1 sq. in.		17645	157.54	.340	181.63	400
1 circ."	1000	13858	123.73	.433	142.65	314.16
0000	454	2854	25.48	2.10	29.38	64.40
000	425	2502	22.33	2.40	25.75	56.40
00	380	2001	17.86	3.00	20.59	45.36
0	340	1600	14.28	3.74	16.47	36.31
No. 1	300	1245	11.12	4.81	12.82	28.27
2	284	1117	9.97	5.37	11.49	25.33
3	259	928	8.28	6.46	9.55	20.07
4	238	783	6.99	7.65	8.06	17.79
5	220	670	5.98	8.96	6.90	15.20
6	203	570	5.09	10.52	5.86	12.94
7	180	448	4.00	13.38	4.61	10.17
8	165	376	3.35	16.39	3.86	8.55
9	148	303	2.71	19.79	3.12	6.88
10	134	249	2.22	24.14	2.55	5.64
11	120	199	1.78	30.10	2.05	4.52
12	109	164	1.46	36.49	1.68	3.73
13	95	124	1.11	48.01	1.28	2.83
14	83	95	.85	62.93	.98	2.16
15	72	72	.64	83.65	.73	1.62
16	65	58	.52	102.6	.59	1.32
17	58	46.58	...	...	...	...
18	49	33.17	...	...	...	...
19	42	24.35	...	...	...	...
20	35	17.93	...	...	...	...
21	32	14.11	...	...	...	...
22	28	10.76	...	...	...	...

TABLE VI.

One nautical or geographic mile av.	....	2029 yds.
One statute mile,	....	1760 "
One " "	....	5280 ft.
One nautical mile equals,	....	(statute miles) 1.153.
One statute " "	....	(Nautical miles) .8674
One metre equals,	....	39.37 in.
One metre equals	....	3.281 ft.
One " "	....	1.094 yds.
One metre equals		three feet, three inches and a third nearly.
One kilometer equals (100 metres)	(Statute miles,	.6214.
One " "	....	(Nautical miles) .539.
One millimeter (thousandth of a metre) equals		.03937 in.
One gramme equals	....	15.44 grns.
One kilogramme	....	(100 grammes) 2.205 lbs.

TABLE OF UNITS.

Unit of Resistance,	....	1 ohm.
One million ohms,	....	1 megohm.
One millionth of an ohm,	....	1 microhm.
Unit of tension,	....	1 volt.
One million volts,	....	1 megavolt.
One millionth of a volt,	....	1 microvolt.
Unit of quantity,	....	1 farad.
One million farads,	....	1 megafarad.
One millionth of a farad,	....	1 microfarad.
Unit of current,	....	1 farad per second.